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Notices of the Aëronautical Society of Great Britain

GENERAL NOTICES

February Elections :—B. WOODWARD ; COMMANDER O. SCHWANN.

March Elections :—A. ARKELL-HARDWICK ; H. F. JACKSON ; LIEUT. LESLIE STEPHENS, R.G.A. ; A. RYAN, B.Sc.

At a meeting of the Council held on February 20, a unanimous vote of thanks to the retiring President, Mr. E. P. Frost, was passed for his great services to the Society during his term of office ; and the Secretary was instructed to communicate the same to the President. The following acknowledgment has been received :—

22nd Feb., 1911.

TO THE SECRETARY OF THE AËRONAUTICAL SOCIETY.

DEAR SIR,

I am in receipt of your letter of the 21st conveying to me the thanks of the Council. I beg to be allowed to offer my sincere and warmest thanks to the Council, not only for the honour they conferred upon me by electing me their President for the past three years, but also for the valuable and very kindly assistance I have always received from every member of the Council, the Secretary, Colonel Tyler, and especially from my friend the former Hon. Secretary, Colonel Fullerton. No man, I think I may say, has of recent years done more for the interests of the Society than Colonel Fullerton. I have also to thank Mr. P. Y. Alexander and others and the members of the Society for the very kind indulgence they have extended to me in my many shortcomings, and lastly for the kindly desire of the Council that I should in the future do what little lies in my power towards the welfare of the old Aëronautical Society.

Believe me to remain,

Yours faithfully,

(Signed) EDWARD P. FROST

Colonel J. D. Fullerton, R.E. (ret.), has been appointed the Society's representative upon the Technical Reserve Committee recently appointed by His Majesty's War Office.

Mr. W. R. Turnbull represented the Society at the Dinner of the Aeronautical Society of America held at New York on April 27, 1911.

"The Flight of Birds," by Giovanni A. Borelli, has been published by the Society as No. 6 of the "Aëronautical Classics" series.

The complete set of "Aëronautical Classics" has also been issued handsomely bound in one volume. Subscribers to the series can obtain binding cases and title-page on application to the publishers.

The Society's recent course of lectures at the Northampton Polytechnic, which are being published in *Aeronautics*, are about to be issued in book-form by this periodical at the price of 5s. net.

Mr. Charles C. Turner is to be congratulated upon obtaining his pilot's certificate in a most creditable fashion, the second qualifying flight being undertaken in a high gusty wind. Mr. Turner is the first member of the Society and the fifth Englishman who has secured his certificate under the new Federation rules.

The Society has loaned the Pilcher monoplane glider to the Scottish Aëronautical Society in order that it may be shown at the Scottish National Exhibition, which will be opened this month at Glasgow.

The three following gentlemen will represent the Society in conference with the Parliamentary Committee on Aeronautics:—The Right Hon. The Lord Montagu of Beaulieu, Mr. Griffith Brewer and Mr. J. W. Dunne.

COMMITTEE NOTICES

Bird Construction Committee The report of this Committee is being immediately published and circulated to members. Non-members may obtain the same upon application to the Secretary of the Society at the price of 10s. 6d. net.

Laboratory Committee This Committee have received three papers which are printed in the present issue. The Committee tender their thanks to Messrs. H. Rollat and Co. for specimens received for testing.

Wings Committee The preliminary report of this Committee is included in the present issue.

LIBRARY NOTICES

The Council desire to thank the following donors for their gifts to the Library:—Mr. A. W. Isenthal for "The Dragon-Fly or Reactive Passive Locomotion" (by Thaddeus Hyatt), 1882; Mr. R. à Court Beadon for a model aeroplane of his own design; Mr. J. D. M. Tinline for an aeroplane propeller; and Mr. A. P. Thurston for a copy of his book entitled "Elementary Aeronautics."

ANNUAL GENERAL MEETING

THE Annual General Meeting of the Aëronautical Society of Great Britain was held at the Royal Society of Arts, on Friday, March 31, 1911, at 8 p.m. The President, E. P. Frost, Esq., occupied the chair, and was supported by Major Baden-Powell (Vice-President), Colonel J. E. Capper, C.B., Colonel J. D. Fullerton, Colonel H. E. Tyler, (Hon. Treasurer) and Messrs. H. P. Becher (Hon. Solicitor) and J. Ward (Hon. Auditor).

The Meeting was well attended.

The President read the notice convening the meeting, and Messrs. D. Barton and H. D. Cutler were appointed as scrutineers of the ballot for the election of the President, Vice-Presidents, Council, and Officers for 1911.

Colonel H. P. Tyler (Hon. Treasurer) read the Report of the Council for the preceding year :—

COUNCIL'S REPORT FOR THE YEAR 1910

The Council congratulates the Society on the importance and scope of the work undertaken during the past year, which compares favourably with any in the forty-six years of its existence. On the other hand the increase in members and consequently in financial resources has been comparatively small, and the Council takes this opportunity to urge upon all members the imperative need for augmenting the membership, which can be accomplished most effectively by individual effort.

The Council has the honour to report that the Society has been asked to furnish a representative upon the Technical Committee on Aeronautics recently appointed by His Majesty's War Office, and Colonel J. D. Fullerton has been nominated to represent the Society.

1. *The Work of the Committees*:—On the regretted retirement from the Hon. Secretaryship of Colonel Fullerton the following Committees were formed at his suggestion : The Bird Construction Committee, the Technical Terms Committee, the Laboratory Committee, and the Wings Committee, to carry out scientific work ; and the Exhibition Committee, the Inventions Committee, the Library and Museum Committee, the Experimental Ground Committee, the Revision of Rules Committee, and the Finance Committee to deal with the business, finance, and the general conduct of the Society.

The Bird Construction Committee is issuing a long and extremely valuable Preliminary Report, which will be published as a separate publication.

The Technical Terms Committee has issued a Preliminary Report which has been published and communicated to the Press.

The Laboratory Committee has instituted a series of experiments on the resistance and strength of component parts of aeroplanes, such as struts and wires, concerning which data are urgently needed. Its work is now proceeding and an Interim Report will shortly be published.

The Wings Committee is continuing investigations and experiments begun in 1909, on the thrust of wings and the practicability of wing-flapping for purposes of dynamic flight.

These scientific Committees carry out perhaps the most important branch of the Society's work, and it is essential that they should be kept supplied with sufficient funds.

The Experimental Ground Committee is still negotiating with regard to the acquisition of a ground, and if sufficient members owning machines would come forward and co-operate, a good private ground could be obtained at a reasonable cost.

Of the remaining Committees it suffices at present to mention the Inventions Committee, which has dealt with a large number of schemes submitted to it by inventors, not only in England, but in many parts of the world.

The Council takes this opportunity to convey its thanks to the Chairman and Members of all the Committees, who have devoted so much time and energy to the service of Aeronautics and of the Society.

2. *Revision of Rules.*—The Council has with the assistance of the Revision of Rules Committee remodelled the Rules.

The President, Council, and Officers are now to be elected annually by ballot of the members, the number of Vice-Presidents and Members of the Council has been increased and an Hon. Treasurer nominated.

These Rules have been circulated to Members, and appear to have met with general approval.

3. *Meetings and Lectures.*—Since the last Annual General Meeting five Ordinary Meetings have been held and important papers have been read by Mr. F. W. Headley, Mr. B. G. Cooper, Mr. W. F. Reid, Mr. W. H. Dines, Mr. F. Handley Page, and Professor G. H. Bryan. A free educational course of six technical lectures on the Theory, Design and Construction of Aeroplanes was delivered on behalf of the Society at the Northampton Polytechnic Institute during November and January last by Mr. J. H. Ledeboer, Mr. A. E. Berriman, Mr. T. W. K. Clarke, Mr. F. H. Lloyd, Captain A. D. Carden, and Mr. B. G. Cooper. These important lectures, which were well attended, formed the first complete course on the theory and practice of the aeroplane given in this country and maintained a high level of excellence.

4. *Publications.*—The editing of the AËRONAUTICAL JOURNAL and other Society publications has been placed in the hands of two Hon. Editors.

The usual quarterly issue of the Journal has been continued and its size has necessarily been increased. In addition to the Report of the Bird Construction Committee previously mentioned, a series of six Aeronautical Classics has been published, in which have been reprinted the most important writings of pioneers in the science. In two cases translations have been made into English. The Society is much indebted to Mr. T. O'B. Hubbard and Mr. J. H. Ledeboer for the trouble they have taken in preparing these very interesting works.

5. *Exhibitions.*—Successful exhibits of aeronautical apparatus, historical relics, rare books, etc., have been made at the Northampton Polytechnic Institute, and at the Aero and Motor Boat Exhibition. While the Council realises that a larger space should have been reserved at the latter Exhibition and better provision made for the comfort of members, lack of funds precluded an extension in this direction.

6. *Medals.*—In July last the Gold Medal of the Society was awarded, in recognition of his distinguished services to Aeronautical Science, to Mr. Octave Chanute, whose recent lamented death has removed one who for many years laboured unceasingly in the cause of dynamic flight and gained the honour, respect and appreciation of the whole aeronautical world.

The Bronze Medal, given annually for the best paper appearing in the AËRONAUTICAL JOURNAL, has been awarded to Mr. B. G. Cooper for his paper on "Some Principles of Propulsion and their Application to Flying Machines."

7. *Library.*—Considerable additions have been made to the Library. A large number of works have been acquired by purchase and donation as well as lantern slides, prints, etc.

8. *Finance.*—The Council regrets to report that the present income is not sufficient to enable the Society's work to be thoroughly carried out. A well-known member, who has assisted the Society for many years, and whose generosity has enabled it to tide over several critical periods, has signified that he is unable to provide future assistance.

This event reduces the income by nearly one-half as compared with the two previous years. New members are therefore urgently needed, and if every member would bring in but one during the present year, the situation would be adequately met. With the rapid development of the science, increased expenditure is necessary to keep pace with the demands that are rightly made upon the Society. Scientific research and experiments, the publication of reports and of the AËRONAUTICAL JOURNAL, the organisation of meetings and lectures, the upkeep of the library, offices and staff, have been carried on as the means available permitted.

A number of schemes for extending and improving the operations of the Society have been debated by the Council, but monetary considerations have tied their hands in almost every instance.

The Council urges upon all members the necessity of assisting the Executive by every means in their power, of contributing, if they are able, to the funds, but above all, of introducing new members.

Dependence is entirely reposed upon the voluntary subscriptions derived from the membership, which in the immediate future must be greatly increased, if it is desired that the Aëronautical Society be equipped with sufficient vitality and resources, both to maintain its unique and distinguished place, and to continue its work for the public good.

Mr. Jas. E. Ward (Hon. Auditor) then read the General Income and Expenditure Account of the Society from December 31, 1909, to December 31, 1910, together with the Balance Sheet as at December 31, 1910.

Upon the President inviting comment a prolonged discussion took place, among those speaking being Mr. A. E. Berriman, Mr. H. Massac Buist, Mr. E. A. Davies, Mr. H. Delacombe, Mr. J. W. Dunne, Mr. J. H. Ledeboer, Mr. B. G. Cooper and Colonel F. G. Stone.

It was finally decided to adjourn the meeting *sine die* without declaring the ballot, and the following resolution was proposed by Mr. Buist, seconded by Colonel F. G. Stone, and carried without a single dissentient :—

> That the following gentlemen be elected to form a Committee of Enquiry, to consider the position of the Society and make suggestions with a view to the benefit of the Society, and with powers to co-opt others if and when they deem it desirable, also to elect an Hon. Secretary :—Messrs. Mervyn O'Gorman, Griffith Brewer, Alex. Ogilvie, F. Handley Page, J. H. Ledeboer, A. E. Berriman, W. T. Douglass, and J. W. Dunne ; and that they be requested to proceed with their business with the utmost despatch and to report to the Members.

It was agreed that the Report of the Committee of Enquiry should be printed and circulated to the Members prior to the next Meeting, which would be convened by the Council immediately they were requested so to do by the Committee of Enquiry, and that such Meeting should have power to give immediate effect to any resolutions passed. On the motion of Mr. Berriman, seconded by Mr. Buist, it was resolved :—

> That this Meeting be adjourned until the Committee of Enquiry are prepared to make their Report.

A vote of thanks to the Council and to the Honorary Officials was proposed by Colonel Stone, seconded by Mr. Berriman, and carried unanimously. The President made suitable acknowledgment, and the Meeting adjourned *sine die*.

GENERAL MEETING

THE First meeting of the Forty-sixth Session of the Aëronautical Society of Great Britain was held at the Royal Society of Arts, John Street, Adelphi, W.C., on Tuesday, February 14, 1911. The Chair was occupied by the President, E. P. Frost, Esq., J.P., D.L.

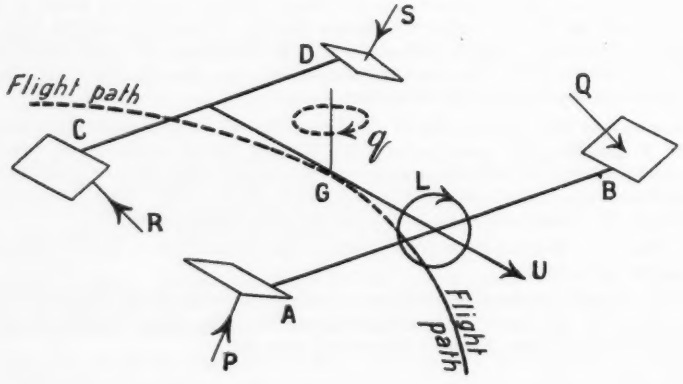
The PRESIDENT said: Ladies and Gentlemen, I am very sorry that I cannot call upon Professor Bryan to read his paper, but Mr. Ledeboer has very kindly consented to do it for him.

THE TURNING MOVEMENT IN AEROPLANES

BY PROFESSOR G. H. BRYAN, SC.D., F.R.S.

One of the most noticeable features of aeroplanes as at present constructed is their tendency to tilt over excessively to the inside, when rounding a curve, and one of the functions of the various warping devices and "ailerons" commonly employed is to enable the operator automatically to counteract this tendency. As is generally known, the cause of the tendency in question is that in circling the outside part of the aeroplanes moves with greater velocity than the inside part, and consequently encounters greater wind pressure causing the machine to tilt over.

Now it seems desirable to minimise as far as possible the need of movable parts and of personal control, and the object of this note is to show that an arrangement is *possible* whereby this tendency may be counteracted in a machine all of whose surfaces are rigidly attached to the framework, and with no sacrifice of lifting power. For this purpose it will be sufficient if the front or main planes and rear or tail planes are both of considerable span, the front planes being bent upwards and the rear planes being bent downwards at their extremities.



To make the explanation simpler, let us suppose that instead of the planes themselves being bent as suggested, it is sought to accomplish the same result by means of four small planes A, B, C, D, fixed at their extremities, the front ones A and B being tilted upwards while the rear planes are tilted downwards. Suppose the machine to be circling in the

direction shown by the dotted line, so that it is moving forward in the direction shown by the arrow U and is in addition rotating about a vertical axis in the direction shown by the round arrow Q.

The effect of rotation will be to impart to the planes A, B a motion from right to left and the planes C, D a motion from left to right.* This motion will cause the air to impinge on the under side of the planes A C and on the upper side of B and D and thrusts P, Q, R, S, will be set up producing a couple L tending to cause the machine to heel over on the outside, and thus tending to counteract the opposite tendency produced by the main aeroplanes. Of course if we assume any simple law of resistance such as the sine law, it is not difficult to write down *formulæ* for the couple L, but this hardly appeared desirable in this short note. If the present suggestion has not already been patented the publication of this note will enable anyone, who cares to take the matter up, to make experiments, and to apply the method if found successful. I have purposely avoided introducing the word "stability" in the present connection, or expressing any opinions as to the practicability of such a plan.

The PRESIDENT: I do not know that it is quite fair to invite discussion on a Paper when the author is not present to reply; at the same time we shall be very pleased to hear what anybody may like to say.

As there appears to be no discussion, it is for me to thank Professor Bryan, the profound scientist, for sending his paper. We should have much preferred to have had the Professor here to have answered any questions that we should have been very glad to have asked him. It is for me now to introduce a gentleman who has come to read his paper. Mr. Handley Page is, I believe, well known to all of you as a practical man in aeronautical work. His lecture will be to me particularly interesting, as an old student of nature, since by costly experimental work of some, I am sorry to say, thirty or even forty years ago, I found that curves and form in every individual feather of the wing of the bird, were most essential to flight and stability. This evening, happily, I am not the lecturer, but a listener only, and I, therefore, will at once call upon Mr. Page to give us his lecture.

THE PRESSURES ON PLANE AND CURVED SURFACES MOVING THROUGH THE AIR

BY F. HANDLEY PAGE

In aeronautical work there are but two factors with which we have to deal, one the pressure on the surfaces used, the other the movement of the resultant centre of pressure under the varying conditions presupposed. This simple division of the subject into two parts dealing respectively with the lifting capacity of the machine and its stability in free flight cannot be followed up by as simple or complete a solution of the problems involved in each. A great deal of theoretical and experimental work has been done, but there have been wide discrepancies in the results obtained owing to the varying conditions under which the experiments have been conducted, the apparatus and the different shapes of test planes and the like that have been employed. In the present paper the principal experimental results have been analysed on a method outlined below,

* "Right" and "left" as they appear on the paper, not as they would appear to a person attached to the machine.

the object being to draw general conclusions as to the effect of aspect ratio, and cross sectional form upon the plane constants, and thus give in a practical form data for the design of future machines. The present inadequate data only show the crying need for further experimental work.

Some Theoretical Considerations

To obtain a law giving the normal pressure on a plane as a continuous function of the angle of incidence of the impinging air from 0 to 90° is impossible owing to the two distinct forms of flow that occur on the back of the plane. From the horizontal position of the plane up to an angle varying in magnitude from 10° to 50° depending on the aspect ratio, shape, and curvature of the plane, the air hugs the back of the plane, the suction due to the rushing air is felt directly on the back of the plane, and the pressure increases continuously as some function of the angle. At angles greater than this critical value the air leaves the back of the plane, a " dead " air region is formed there, and any reduced pressure or suction on the plane back tending to increase the total " lift " is then solely due to the drag of the " live air " stream at the edges of this dead air region. Once the stream has left the plane back the drag will be fairly uniform. The conditions are, however, by no means those of equilibrium especially near the critical point, and great care must always be exercised in the selection of the means of fixing the test plane to ensure the form of flow being unaffected by it. It is mainly owing to the varying plane cross sections used and the methods adopted for the fixing that the great discrepancies occur which are met with in aeronautical experiments. The plane fixing may be such as to entirely upset the conditions prevailing were the plane in free flight, and the pressure at the plane back no longer represents that due to the plane alone. Temperature variations during the experiment are also liable to cause serious errors unless carefully noted and allowed for.

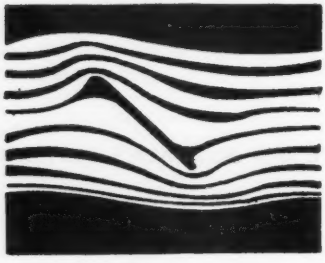


Fig. 1

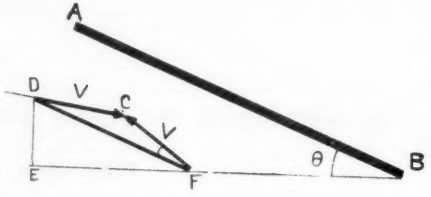


Fig. 2

In aeronautical work, whether it is the propeller or supporting plane question, the angles of inclination to the flight path are small, and the problem is confined within those limits between which the air hugs the back of the plane. The working point is selected where there is a minimum eddy disturbance, and a maximum ratio of "lift" to " drift."

The air on meeting the plane divides into two streams, as pictured in Fig. 1,* the streams meeting again at the back of the plane. At high velocities the eddies and turbulence at the rear of the plane completely obscure this, but up to the critical angle at which the " live " air stream leaves the plane back, the effect is still the same, and the reduced pressure at the back may be assumed to be some multiple of the front pressure, an assumption that is fairly consistent with practical results.

* Hele Shaw trans. I.N.A.

Turning again to Fig. 1, let

A=area of the plane=span × chord.

S_1A=cross section of the stream which is deflected upward by the plane.

S_2A=cross section of the stream which is deflected downward by the plane.

The change of momentum of the top stream will be (see Fig. 2)

$$2S_1A.V^2.\cos\frac{\theta}{2}.\frac{w}{g}$$ where θ=the angle of incidence.

V=velocity of the plane through the air.

w=density of the air.

g=acceleration due to gravity.

The "lift" due to this will be

$$-S_1AV^2\sin\theta.\frac{w}{g} \quad \ldots\ldots(1)$$

and the drift will be

$$S_1AV^2.(1+\cos\theta).\frac{w}{g} \quad \ldots\ldots(2).$$

Similarly for the downward stream (see Fig. 3)

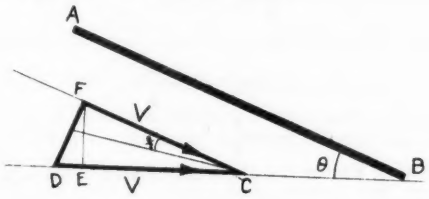


FIG. 3

The change of momentum of the stream will be

$$2S_2AV^2\sin\frac{\theta}{2}.\frac{w}{g}.$$

The "lift" due to this will be

$$S_2AV^2\sin\theta\frac{w}{g} \quad \ldots\ldots(3).$$

The "drift" will be

$$S_2AV^2(1-\cos\theta)\frac{w}{g}. \quad \ldots\ldots(4).$$

The total "lift" on the front of the plane will be

$$=S_2AV^2\sin\theta.\frac{w}{g}-S_1AV^2\sin\theta\frac{w}{g}$$

$$=\frac{w}{g}A.V.^2\sin\theta(S_2-S_1) \quad \ldots\ldots(5).$$

The total "drift" will be

$$=S_2AV^2\frac{w}{g}(1-\cos\theta)+S_1AV^2(1+\cos\theta)\frac{w}{g}$$

$$=\frac{w}{g}.AV^2(S_1+S_2-\cos\theta\left\{S_2-S_1\right\}) \quad \ldots\ldots(6).$$

It is necessary now to find the relation between S_1 and S_2, the "Sweep Factors" of the upper and lower streams.

At the point A in Fig. 1 where the streams divide the stream velocity is nil, and the pressure is that due to the aerodynamic "head." At this point there must be no flow either up or down the plane, the pressure parallel to the plane due to the upward being balanced by that due to the downward stream.

We can imagine the pressure of the upward stream parallel to the plane setting up an imaginary stream of some cross section S_3A flowing downward parallel to the plane.

The change of momentum of this stream would be

$$2S_3AV^2\frac{w}{g}\sin\frac{\theta}{2}$$

and it would be equal and opposite to that of the upward stream, or

$$2S_3AV^2\frac{w}{g}\sin\frac{\theta}{2}=2S_1AV^2\frac{w}{g}\cos\frac{\theta}{2},$$

$$\text{or } S_3=S_1\cos\frac{\theta}{2}.$$

Similarly by imagining another stream of section S_4A set up by the downward stream we have,

$$2S_4AV^2\frac{w}{g}\cos\frac{\theta}{2}=2S_2AV^2\frac{w}{g}\sin\frac{\theta}{2}$$

$$S_4=S_2\tan\frac{\theta}{2}.$$

For the point A to be in equilibrium $S_4=S_3$

$$\text{or } \frac{S_1}{S_2}=\tan^2\frac{\theta}{2}$$

$$\text{and } S_1+S_2=S_2\left(1+\tan^2\frac{\theta}{2}\right)$$

$$=S_2\sec^2\frac{\theta}{2}.$$

And if S is the total "Sweep Factor" of the whole stream dealt with,

$$S=S_1+S_2=S_2\sec^2\frac{\theta}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7).$$

$$S_2-S_1=S_2\left(1-\tan^2\frac{\theta}{2}\right)$$

$$=S\cos^2\frac{\theta}{2}\left(1-\tan^2\frac{\theta}{2}\right)$$

$$=S.\cos\theta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8),$$

Substituting (8) in (5),

The total "lift" on the front of the plane is

$$=\frac{w}{g}.AV^2\sin\theta.S\cos\theta$$

$$=S.\frac{w}{g}.AV^2\frac{\sin2\theta}{2}$$

$$\text{or for small angles}=S.\frac{w}{g}.AV^2\theta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9).$$

The total "drift" on the front of the plane is

$$=\frac{w}{g}AV^2\left(S-S\cos^2\theta\right)$$

$$=S.\frac{w}{g}.A.V.^2\sin^2\theta,$$

$$\text{or for small angles, drift}=S.\frac{w}{g}.AV^2\theta^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(10).$$

These formulæ will also hold true with appropriate increases in the value of S for the total pressure on the plane, since we may assume for practical work that the suction on the back is some multiple of the pressure upon the front of the plane.

By considering the stream as deflected downward only M. Rateau has developed as an extension of Rankin's original method similar formulæ giving

$$\text{"Lift"}=S.\frac{w}{g}.AV^2\sin\theta,$$

$$\text{and "Drift"} = 2S.\frac{w}{g}AV^2\sin^2\frac{\theta}{2}$$

or with the small angles used

$$\text{"Lift"} = S.\frac{w}{g}AV^2\theta,$$

$$\text{and "Drift"} = S.\frac{w}{g}AV^2\frac{\theta^2}{2}$$

These give the same values at low values of θ for the lift, but the drift is halved, a result which does not agree with experimental figures.

Neither of these methods have so far taken account of any increase in the "drift" values, owing to the planes not being of stream line form, or of any increased resistance due to eddies set up by irregularities in the plane surface. M. Rateau has assumed that the velocity when leaving the plane is reduced by an amount ϵV, giving a final value for it of

$$V(1—).$$

His drift formula then becomes

$$\text{"Drift"} = S.\frac{w}{g}.AV^2\left(\frac{\theta^2}{2}+\epsilon\right).$$

M. Soreau has pointed out that a formula more in accord with experiment is

$$\text{"Drift'} = S.\frac{w}{g}.AV^2\left(a\alpha^2+b\alpha+c\right).$$

Where a, b and c are constants, a having the maximum value of 0·5 indicated above, and α the angle of incidence of the chord which is different in value to the angle of deviation for a curved plane.

The maximum value of 1 for a deduced from formula (10) agrees best with experiment, and we thus have

$$\text{Drift} = S.\frac{w}{g}AV^2\,(a\alpha^2 + b\alpha + c) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(11).$$

With a maximum value of about 1 for a.

It is interesting now that these relations are found to see how the maximum ratio of "lift" to "drift" and the angle of incidence at which this occurs depend upon the values of the various constants.

If we assume a curved plane we must add an angle d to the angle of incidence α of the chord to obtain the total angle of deviation δ of the air stream.

$$\text{Then "Lift"} = S.\frac{w}{g}AV^2\,(\alpha + d)$$

$$\text{Drift} = S.\frac{w}{g}AV^2\,(a\alpha^2+b\alpha+c)$$

$$\frac{\text{Lift}}{\text{Drift}} = \frac{\alpha+d}{a\alpha^2+b\alpha+c} = e$$

To find the maximum value of e, differentiate and equate to zero.

$$\frac{de}{d\alpha} = \frac{(a\alpha^2+b\alpha+c)—(\alpha+d)(2a\alpha+b)}{(a\alpha^2+b\alpha+c)^2} = o,$$

$$\text{or } a\alpha^2+b\alpha+c = 2a\alpha^2+\alpha(2ad+b)+bd,$$

$$\text{or } a\alpha^2+2ad\alpha+bd—c=o$$

$$\alpha = —d+\sqrt{d^2—\left(\frac{bd—c}{a}\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(12).$$

For a flat plane where d=o and the angle of deviation corresponds to the angle of incidence of the chord,

$$\alpha = \sqrt{\frac{c}{a}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(13),$$

$$\text{and e max.} = \frac{\sqrt{\frac{c}{a}}}{2c + b\sqrt{\frac{c}{a}}}$$

For a thin plane such as some that have been used in the experiments analysed below, b=o, and

$$\therefore \text{ e max.} = \frac{\sqrt{\frac{c}{a}}}{2c} = \frac{1}{\sqrt{4ac}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14).$$

Formulæ (13) and (14) suggest a quick and simple method for determining the efficiency of a flat plane. In this case "a" is nearly equal to 1, and a simple determination of the "drift" at zero angle of incidence will give the maximum ratio of the "lift" to "drift," and also the angle at which this is obtained.

An Analysis of Some Experiments

(A) The Lift on a Flat Plane.

It is now necessary to turn to experimental work to find values for the sweep factor S, and the constants a, b, and c in the drift formulæ.

The sweep factor is determined from equation (9) above.

$$\text{Lift} = S.\frac{w}{g}AV^2\theta.$$

Knowing the lift per sq. unit of surface, the velocity of the impinging air, the density of the air at the temperature at which the experiments were carried out, and the angles at which the lifts are obtained,

$$S = \frac{P}{\frac{w}{g}AV^2\theta} \quad \text{where P is the lift.}$$

In Fig. 4 the results are given of most of the well-known experiments on the pressure on inclined flat plates exposed to a current of air. The ordinates are the coefficients

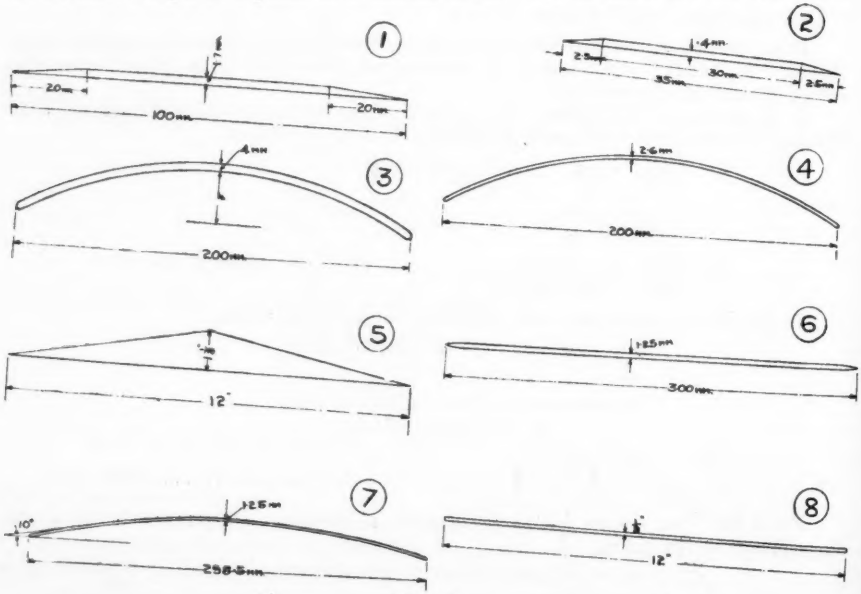


Fig. 6

$\phi = S\theta$ of total pressure on the plane, the abscissæ the angles of inclination of the plane to the horizontal. Fig. 5 shows on a larger scale the part of the curves which are most interesting for aeronautical work—from 0 to 20°. The cross sections of the planes are shown in Fig. 6. The deduced values of the sweep factor, the key to the various curves,

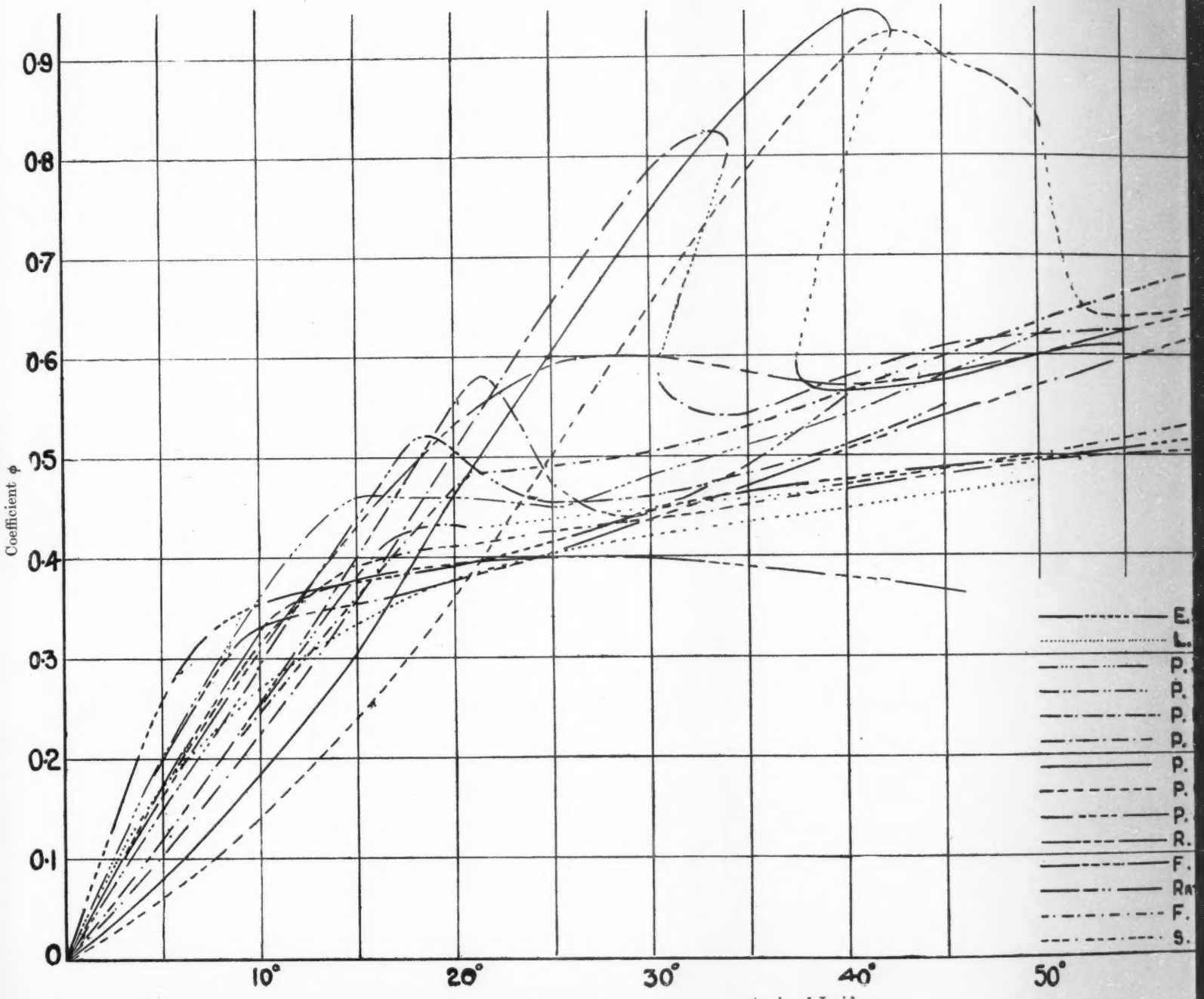
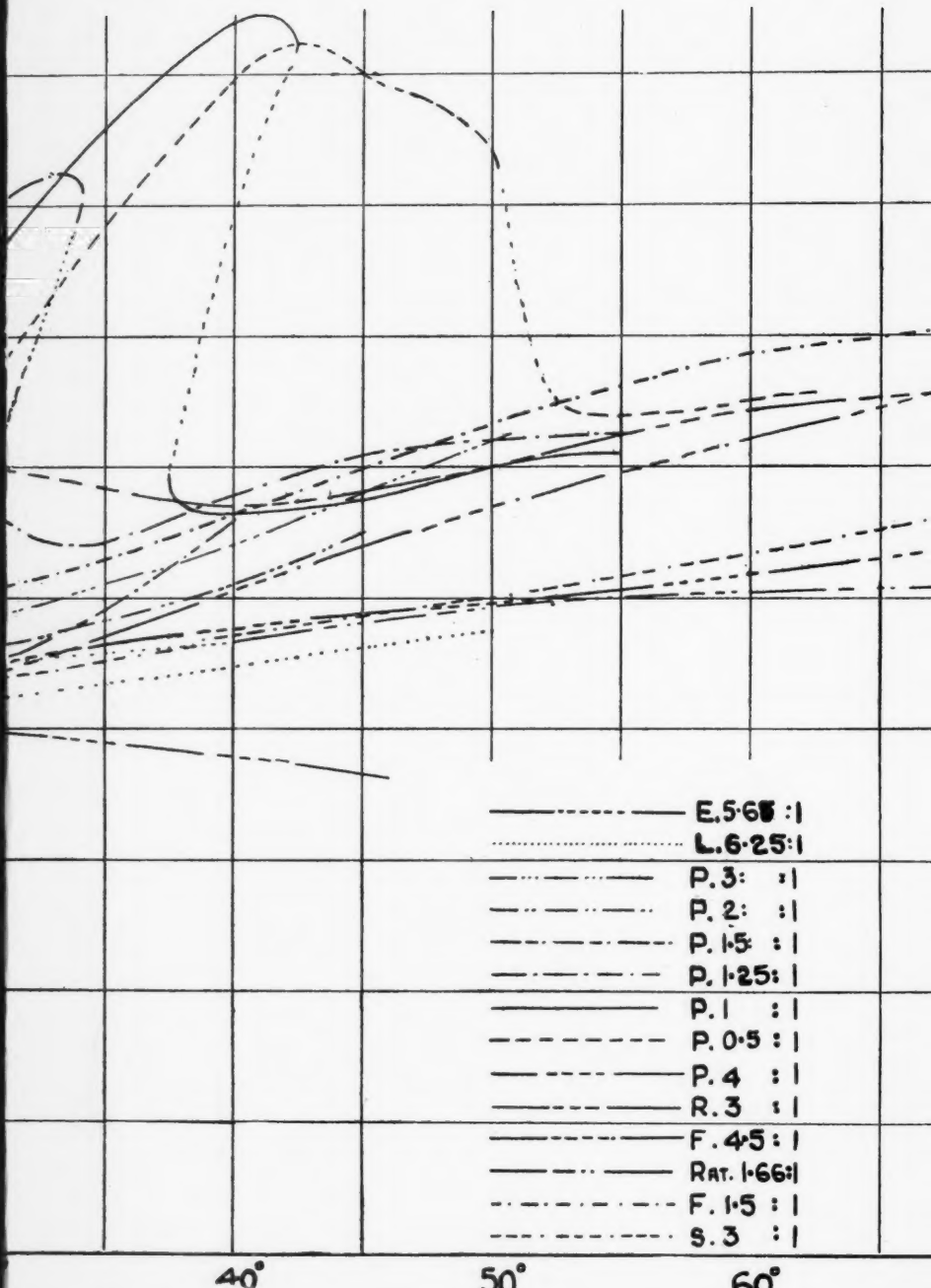
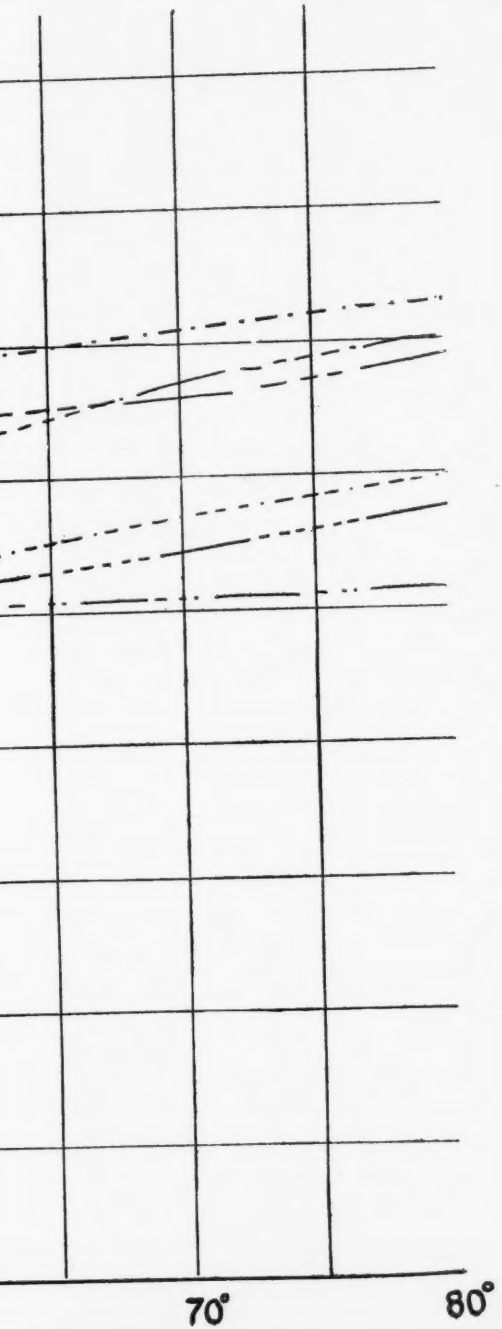

0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0
Coefficient φ
10°
20°
30°
40°
50°
Angle of Incidence
E.
L.
P.
P.
P.
P.
P.
P.
P.
R.
F.
Ra
F.
S.

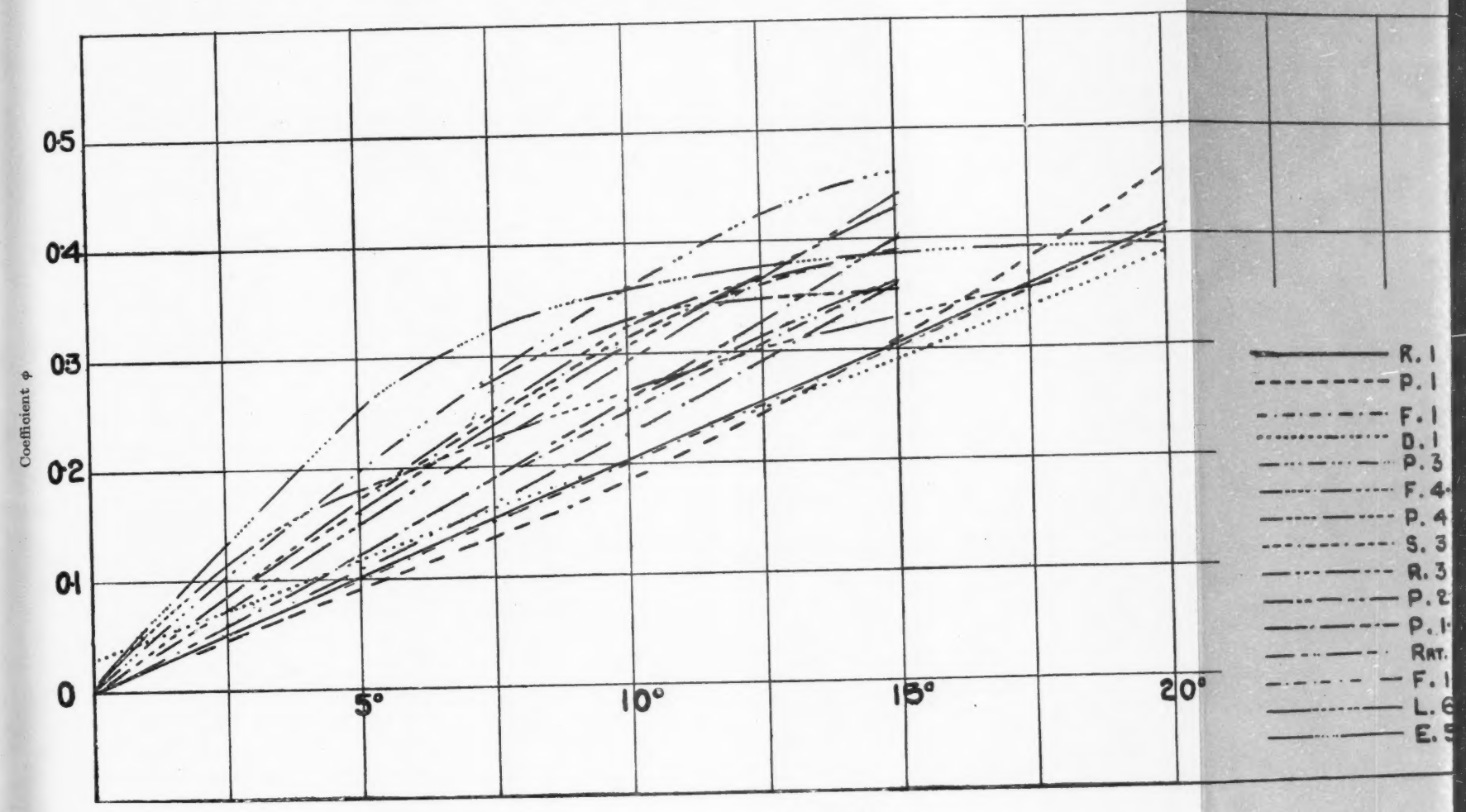
FIG. 4



Angle of Incidence

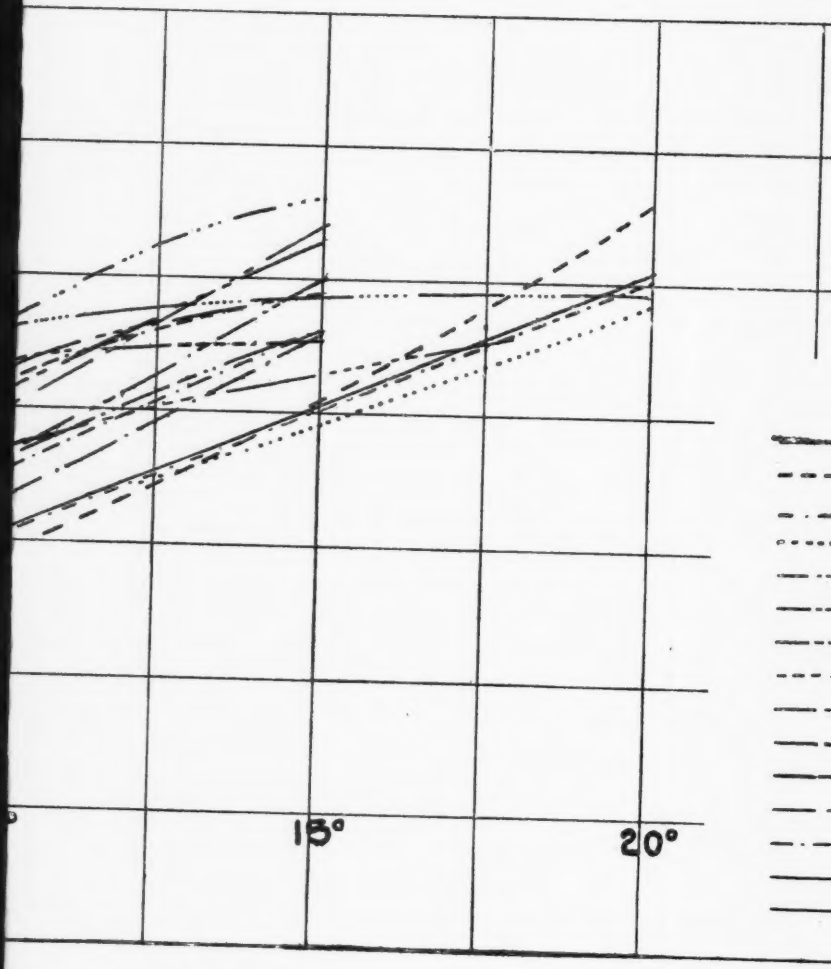
FIG. 4


70°
80°



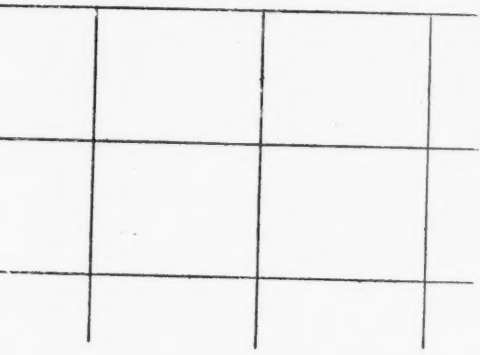
Angle of Incidence

FIG. 5



Angle of Incidence

FIG. 5



R. 1 : 1
P. 1 : 1
F. 1 : 1
D. 1 : 1
P. 3 : 1
F. 4-5 : 1
P. 4 : 1
S. 3 : 1
R. 3 : 1
P. 2 : 1
P. 1-5 : 1
RAT. 1-66 : 1
F. 1-5 : 1
L. 6-25 : 1
E. 5-65 : 1

and the method of experimenting employed, are given in Table I.

The latter may be divided into four heads.

A. The planes were dropped vertically on a guiding cable through the air.

B. The planes were tested in a "wind tunnel."

C. The planes were tested on a whirling table, measurements being made manometrically of the pressure distribution, and the whole summed up.

D. The planes were tested on a whirling table, and the total pressure measured.

TABLE I.

"SWEEP FACTOR" VALUES FOR FLAT PLANES OF DIFFERENT ASPECT RATIOS

Experimenter.	Ref. No.	Method used.	Size of Planes.	Max. thickness.	Cross Section.	Aspect Ratio.	Sweep Factor.
			cms.	mm.			
Eiffel (a).....	E. 1	A	50·0×50·0	—		1	1·1
,, (b)	E. 5·65	B	85×15	3		5·66	3·09
Finzi (c)	F. 4·5	C	45×10	4		4·5	2·35
	F. 1·5		45×30·5	4		1·48	1·35
	F. 1		45×45	4		1	1·12
Dines (d)	D. 1	D	30·5×30·5	2·86	Fig. 6 (5)	1	1·02
Rateau (e)	Rt.1·66	B	50·0×30·0	1·25	Fig. 6 (6)	1·66	1·5
Riabouchinski (f)	R. 1	B	30·0×30·0	1·7		1	1·14
	R. 3	B	30·0×10·0	1·7	Fig. 6 (1)	3	1·75
Stanton (g)	S. 3	B	7·62×2·54	—		3	1·82
Langley (h)	L. 6·25	O	76·2×12·2	3·08		6·25	2·5
	L. 1	D	30·5×30·5	3·08	Fig. 6 (8)	1	1·15
Gottingen (i)	P. 1	B	35×35	4	Fig. 6 (2)	1	1·1
	P. 1·25	B	43·7×35	4	Fig. 6 (2)	1·25	1·3
	P. 1·5	B	52·5×35	4	Fig. 6 (2)	1·5	1·45
	P. 2	B	70×35	4	Fig. 6 (2)	2	1·67
	P. 3	B	105×35	4	Fig. 6 (2)	3	2·1
	P. 4	B	80×20	4	Fig. 6 (3)	4	2·05

For reference letters (a), (b), &c., see Bibliography.
For reference Nos. E. 1., F. 4·5, &c., see Figs. 4 and 5.
For cross sections see Fig. 6.

Note.—The values of the coefficient $\phi = S\theta$ have been plotted as ordinates rather than Ky in the formula

$$P = KyAV^2,$$

as the latter coefficient contains the constants $\frac{w}{g}$ which vary in value with the system of units used. Φ is independent of the system and is applicable therefore to both metric and British units.

In Fig. 7 the "sweep factor" values are plotted as ordinates against the corresponding aspect ratio values, and a straight line drawn through the mean values. It would seem that at higher aspect ratios the curve should start to droop, the sweep factor reaching a maximum value of the order of 3·5 to 4 if the aspect ratio were infinite. In the absence of definite data the curve has been drawn as a straight line right through. As drawn the law of the curve is

$$S = \cdot 85 + \cdot 35n \quad \ldots\ldots\ldots\

(B) The Lift on Curved Planes.

Various experiments on curved planes have been dealt with in a similar way to that used with the flat ones. The results are given in Table II. The planes all had a curvature of about 1 in 14, the curvature the same on both sides. The "aspect ratio" and "sweep" factor curve for the curved planes is plotted at Fig. 7 (2).

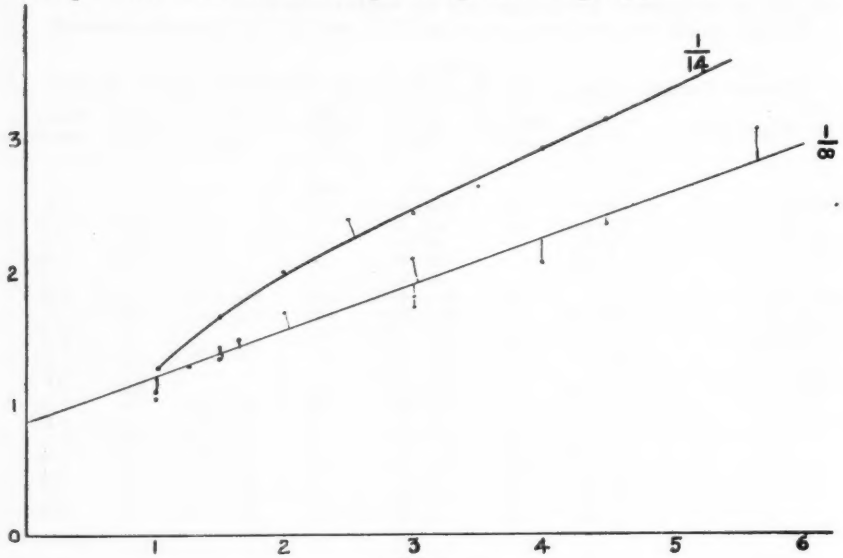


FIG. 7

TABLE II.

"SWEEP FACTOR" VALUES OF CURVED PLANES OF DIFFERENT ASPECT RATIO

Experimenter.	Ref. No.	Method used.	Size of Planes.	Max. thickness.	Cross Section.	Curvature.	Aspect Ratio.	Sweep.
			cms.	mm.				
Eiffel (b)	E. 6·1	B	90×15	3		1/13·5	6	2·05
Riabouchinsky (f)	R. 3	B	30×10	1·7	Fig. 6 (1)	1/16	3	2·1
Lillienthal.....	L. 3	—	128×40			1/12	3·18	2·43
Gottingen (i) ..	P. 1	B	20×20	2·6	Fig. 6 (4)	1/13·5	1	1·26
	P. 1·5	B	30×20	2·6	Fig. 6 (4)	1/13·5	1·5	1·64
	P. 2	B	40×20	2·6	Fig. 6 (4)	1/13·4	2	2·0
	P. 2·5	B	55×20	2·6	Fig. 6 (4)	1/13·2	2·75	2·4
	P. 3·5	B	70×20	2·6	Fig. 6 (4)	1/13·4	3·5	2·65
	P. 4	B	80×20	2·6	Fig. 6 (4)	1/13·1	4	2·97
	P. 4·5	B	90×20	2·6	Fig. 6 (4)	1/13·3	4·5	3·17
	P. 5	B	105×20	2·6	Fig. 6 (4)	1/13·3	5·25	3·65

For reference letters (a), (b), &c., see Bibliography.
For reference Nos. E. 1., F. 4·5, &c., see Fig. 8.
For cross sections, see Fig. 6.

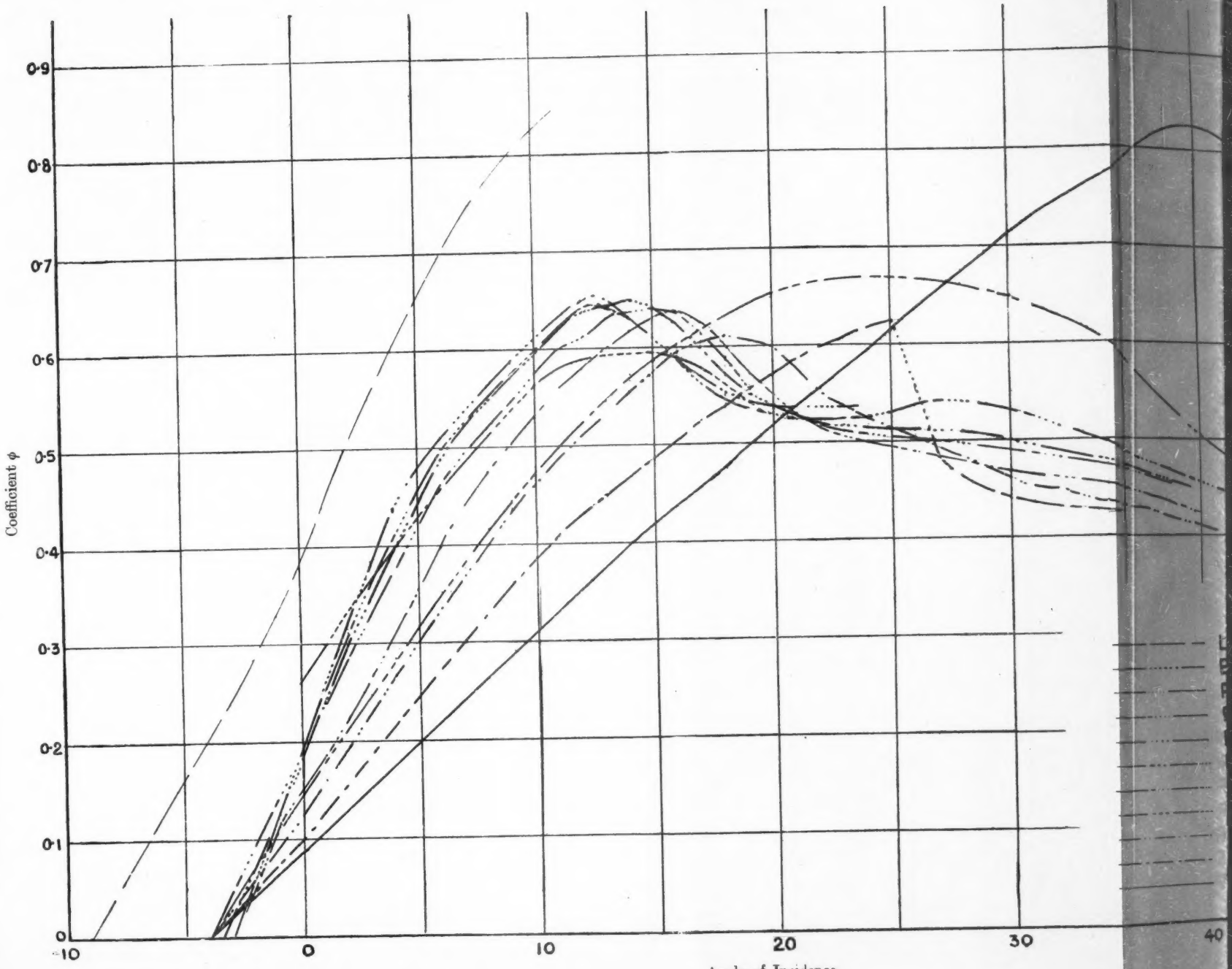
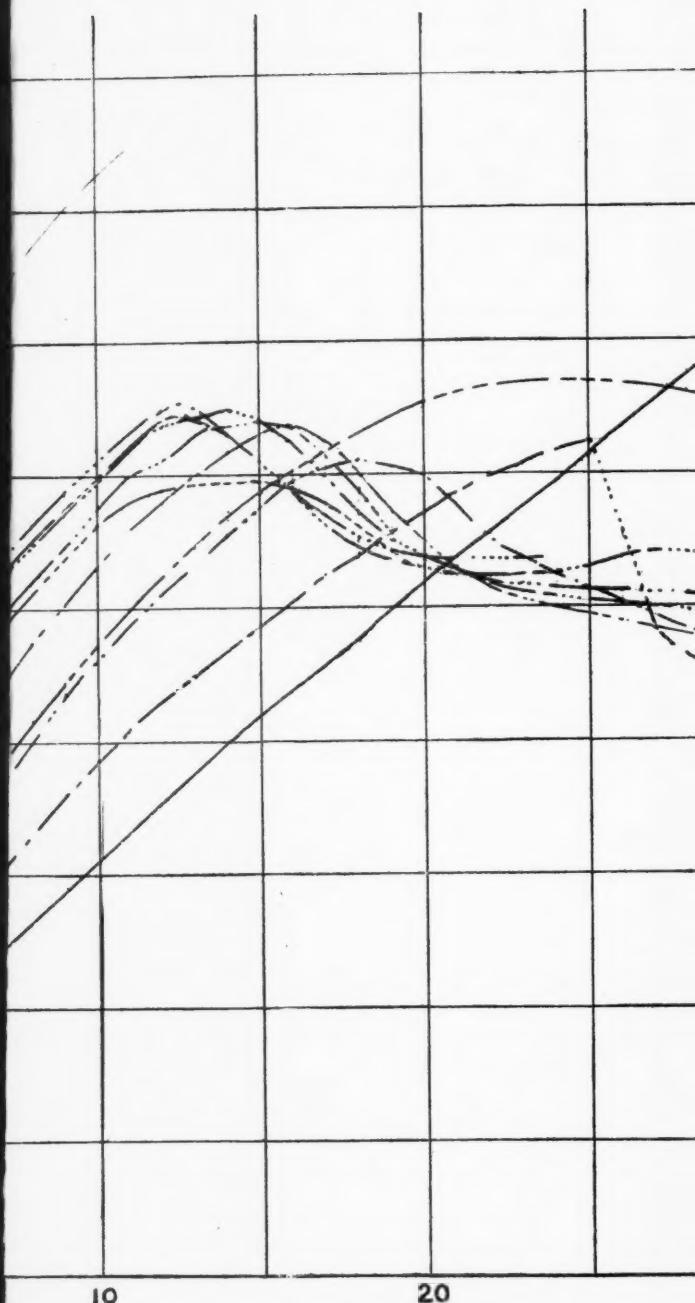
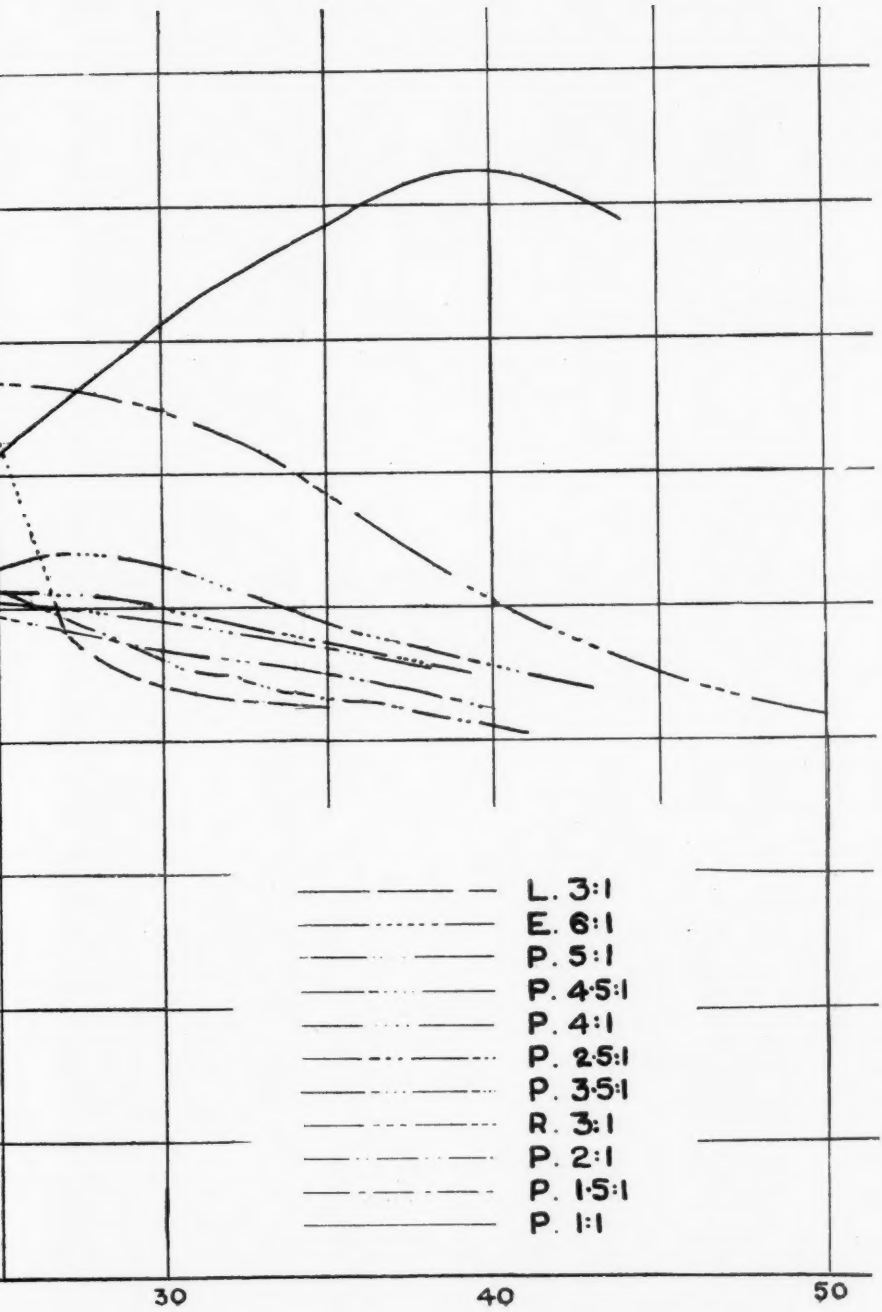

0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0
Coefficient φ
-10
0
10
20
30
40
Angle of Incidence

Fig. 8



Angle of Incidence

FIG. 8


L. 3:1
E. 6:1
P. 5:1
P. 4·5:1
P. 4:1
P. 2·5:1
P. 3·5:1
R. 3:1
P. 2:1
P. 1·5:1
P. 1:1
30
40
50

It is surprising how well the early results of Lilienthal agree with the latest experiments at Gottingen. Previously considered high in value, this increase compared with a square flat plane is due to the higher value of the aspect ratio and the curvature of the plane. The angle θ· with a curved plane is, of course, the total angle of deviation of the air, greater than the angle of incidence α of the chord to the horizontal by an angle d, the value of the latter depending on the curvature of the plane.

In the case of the plane with a curvature of 1 in 14 the sweep factor is approximately 30 per cent. greater than that with a flat plane of the same aspect ratio, but the actual ratio of the two pressure values will depend on the curvature chosen. The curves in Fig. 9 show two series of test planes of aspect ratio, 4 to 1 and 3 to 1 respectively, with varying curvatures, and the figures in Table III. give the corresponding sweep factors deduced. A "sweep factor" curve is not plotted for varying curvatures, the writer's practice being to increase the flat plane sweep factor by a percentage proper to the curvature and cross section employed, and one which is in accordance with the experimental results.

TABLE III.

SWEEP FACTORS OF PLANES OF TWO ASPECT RATIOS AND VARYING CURVATURE

Experimenter.	Ref. No.	Method used	Size of Planes.	Max. thickness.	Cross Section.	Curvature.	Aspect Ratio.	Sweep.
			cms.	mm.				
Riabouchinski (f)	R $\frac{1}{\infty}$	B	30·0×10·0	1·7	Fig. 6 (1)	$\frac{1}{\infty}$	3 : 1	1·75
	R $\frac{1}{30}$	B	30·0×10·0	1·7	Fig. 6 (1)	$\frac{1}{30}$	3 : 1	1·61
	R $\frac{1}{20}$	B	30·0×10·0	1·7	Fig. 6 (1)	$\frac{1}{20}$	3 : 1	1·62
	R $\frac{1}{16}$	B	30·0×10·0	1·7	Fig. 6 (1)	$\frac{1}{16}$	3 : 1	1·92
	R $\frac{1}{12}$	B	30·0×10·0	1·7	Fig. 6 (1)	$\frac{1}{12}$	3 : 1	2.
	R $\frac{1}{8}$	B	30×10	1·7	Fig. 6 (1)	$\frac{1}{8}$	3 : 1	2·27
Gottingen (i) ..	G $\frac{1}{\infty}$	B	80×20	4	Fig. 6 (3)	$\frac{1}{\infty}$	4 : 1	2.
	G $\frac{1}{60}$	B	80×20	4	Fig. 6 (3)	$\frac{1}{60}$	4 : 1	1·88
	G $\frac{1}{25}$	B	80×20	4	Fig. 6 (3)	$\frac{1}{25}$	4 : 1	2·22
	G $\frac{1}{20}$	B	80×20	4	Fig. 6 (3)	$\frac{1}{20}$	4 : 1	2·5
	G $\frac{1}{14}$	B	80×20	4	Fig. 6 (3)	$\frac{1}{14}$	4 : 1	3·2
	G $\frac{1}{12}$	B	80×20	4	Fig. 6 (3)	$\frac{1}{12}$	4 : 1	3·08
	G $\frac{1}{9·8}$	B	80×20	4	Fig. 6 (3)	$\frac{1}{9·8}$	4 : 1	4·35

For reference letters (a), (b), &c., see Bibliography.
For reference Nos. E. 1., F. 4·5, &c., see Fig. 9.
For cross sections, see Fig. 6.

In summarising the experimental results there are a few general characteristic features of the "lift" curves that are very noticeable. Firstly, the "aspect ratio" has a definite effect upon the lift at a given angle of inclination, the higher the aspect ratio, the higher the value of the pressure. Secondly, the critical angle at which the "live" air leaves the plane back is reached earlier in the case of planes of high aspect

ratio, and the latter accordingly do not have such high maximum values as the planes of lower aspect ratio.

Thirdly, in dealing with curved planes the aspect ratio and sweep factor effect still obtains, the lift may be calculated in the same manner as for a flat plane with a suitable increase in the sweep factor and an addition to the angle of inclination to give the true angle of deviation.

The effect of "aspect ratio" upon the "sweep factor" is due to variations in the suction at the plane back. Finzi's experiments show that the front plane pressures are practically constant at any given angle of incidence, no matter what the aspect ratio is, whereas the back suctions vary considerably. The reason appears to be that with a plane of large aspect ratio the air has comparatively more easy access to the "leaving edge" of the plane, and the pressure is consequently exerted over a greater area than if the aspect ratio were small. With planes of high aspect ratio there is not the same facility for the "feeding in" of fresh air at the plane sides to act as a link between the plane and "live stream," and therefore the live stream leaves the plane back at an earlier stage than in the case of the plane of lower aspect ratio.

(c) The "Drift" of a Plane.

The "sweep factor" of the plane is determined from the "lift" experiments, and it remains now but to interpolate the values of the factors in the formula

$$\text{Drift} = S.\frac{w}{g}.AV^2\left(a\alpha^2 + b\alpha + c\right)$$

to give the values of the constants a, b, c.

This procedure has been gone through for those planes on which the horizontal pressures have been recorded. Tables IV, V, and VI give these figures for the planes whose other constants have already been recorded in Tables I, II, and III.

TABLE IV.

VALUES OF "DRIFT" CONSTANTS OF FLAT PLANES (See Table I. and Fig. 10.)

Experimenter.	Size of Planes.	a.	b.	c.
	cms.			
Rateau	50×30	·77	·04	0
Riabouchinski	30×10	·81	0	·0043
Gottingen	80×20	·82	·0122	·0045

TABLE V.

VALUES OF "DRIFT" CONSTANTS OF CURVED PLANES (CURVATURE $\frac{1}{14}$) OF VARYING ASPECT RATIO

(See Table II. and Fig. 11).

Experimenter.	Ref. No.	Size of Planes.	A.	B.	C.
		cms.			
Eiffel	E. 6	90×15	·815	0	·00175
Riabouchinski	R. 3	30×10	·835	—·026	·0136
Lilienthal	L. 3	128×40	1	·304	—·0084
Gottingen	G. 1	20×20	·86	·02	·023
	G. 1·5	30×20	·74	·0245	·0177
	G. 2·5	55×20	·505	·0167	·012
	G. 4	80×20	·35	·027	·0095
	G. 5·25	90×20	·3	·0236	·0082

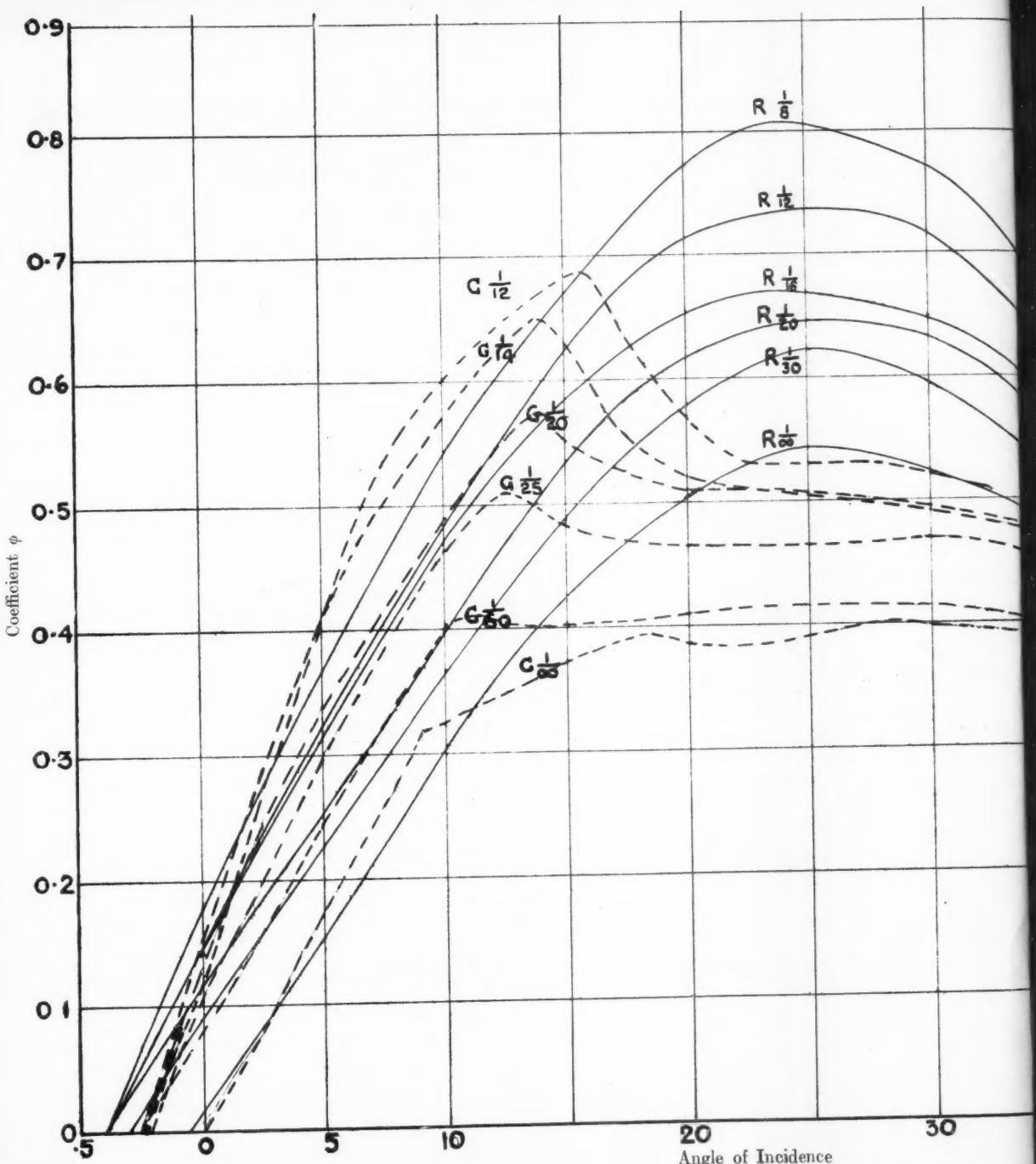
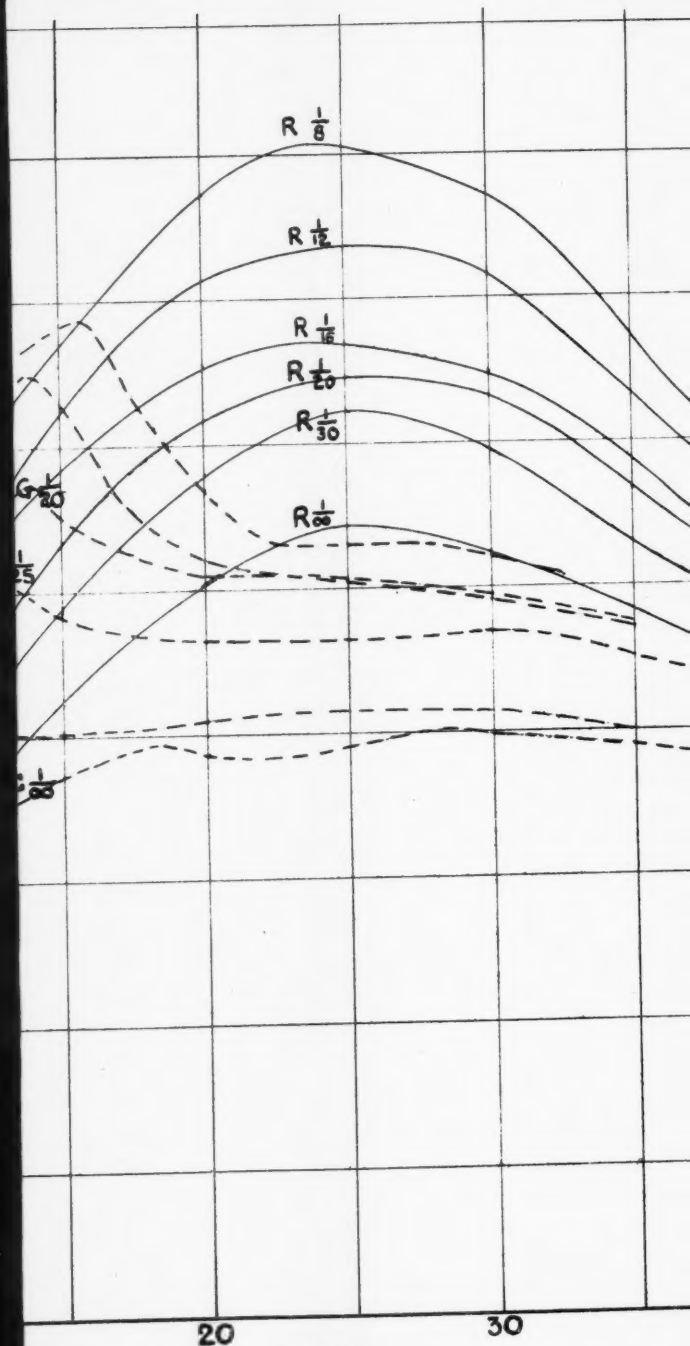

0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0 1
0
·5
0
5
10
20
30
Coefficient φ
Angle of Incidence
R 1/8
R 1/12
R 1/16
R 1/20
R 1/30
R 1/60
C 1/12
C 1/14
C 1/20
C 1/25
C 1/60
C 1/60

FIG. 9



Angle of Incidence

FIG. 9

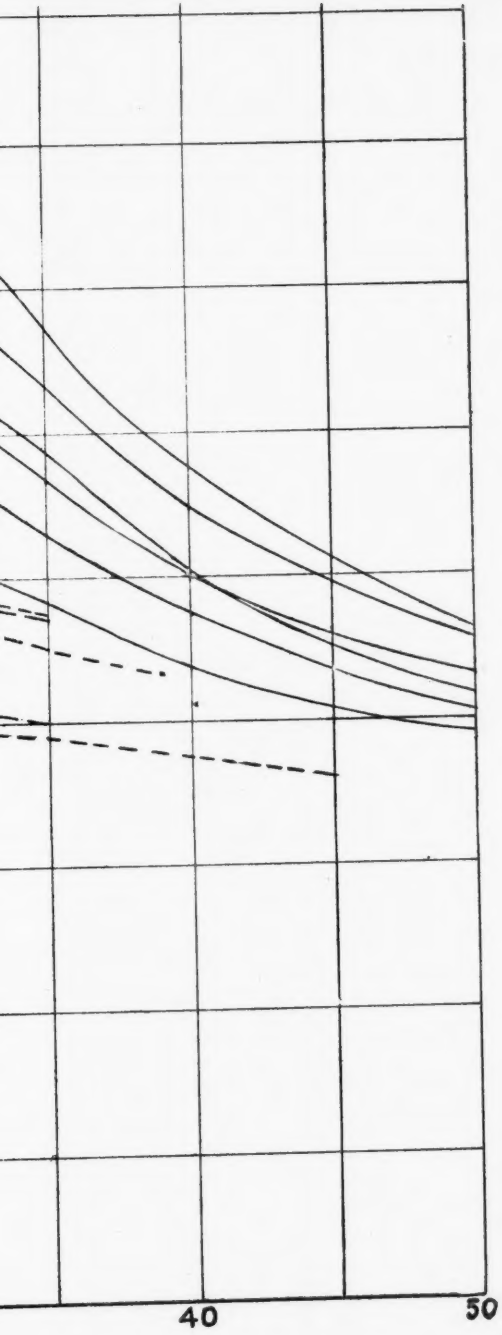

40
50

TABLE VI.

VALUES OF "DRIFT" CONSTANTS FOR CURVED PLANES OF VARYING CURVATURE
(See also Table III. and Fig. 12.)

Experimenter.	Ref. No.	Size of Planes.	Curvature.	A.	B.	C.
		cms.				
Riabouchinski ..	R $\frac{1}{\infty}$	30×10	$\frac{1}{\infty}$	·81	0	·0043
	R $\frac{1}{30}$	30×10	$\frac{1}{30}$	1·17	—·087	·00745
	R $\frac{1}{20}$	30×10	$\frac{1}{20}$	1	—·052	·0105
	R $\frac{1}{16}$	30×10	$\frac{1}{16}$	·835	—·026	·0136
	R $\frac{1}{12}$	30×10	$\frac{1}{12}$	·45	0	·0165
	R $\frac{1}{8}$	30×10	$\frac{1}{8}$	·575	·0176	·025
Gottingen	G $\frac{1}{\infty}$	80×20	$\frac{1}{\infty}$	·82	·0122	·0045
	G $\frac{1}{25}$	80×20	$\frac{1}{25}$	·7	—·0067	·0081
	G $\frac{1}{20}$	80×20	$\frac{1}{20}$	·61	—·016	·0088
	G $\frac{1}{12}$	80×20	$\frac{1}{12}$	·324	·0146	·0107
	G $\frac{1}{9·8}$	80×20	$\frac{1}{9·8}$	·1	·053	·009

The agreement between the "drift" results is by no means as good as that for the "lift." The forces to be measured are so much smaller that the errors of observation are much greater, and deduction drawn from the results can only to a large extent be

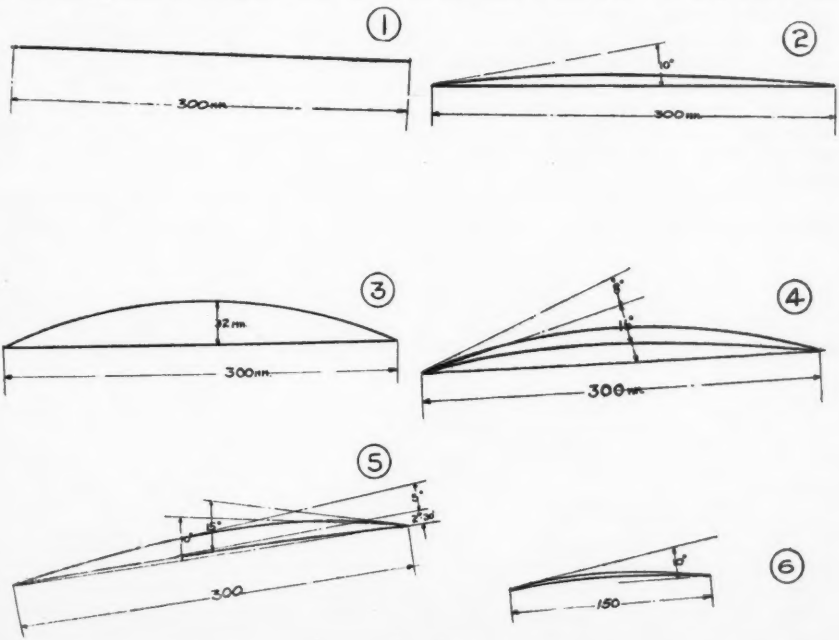


FIG. 14

comparative. To assess the correct figures for any given plane, data must be used obtained from tests of a similar form.

With a given aspect ratio the product s × a, and therefore to greater extent "a," decreases with increase of curvature, the value being about 1 for planes of small curvature. The product s × c follows the same variation as s × a, but the coefficient c is more nearly constant provided the sectional form remains unaltered. The thickness of the plane exerts its influence on the value of "b," the thinner the plane the smaller the value. With very thin flat planes its value can be taken as zero.

All these curved planes tested were of the same curvature above and below, and were formed of circular arcs. Experiments are greatly needed on planes of sectional forms more generally used in aeroplane work, for it by no means follows that a thin plane is the one most suitable. M. Rateau carried out a series of tests on some planes 10 × 30 cms. area—1·66 : 1 aspect ratio—of the cross sectional forms of Fig. 14. The lift/drift values obtained are given in the curves of Fig. 13. The ones which gave the best results are the two thickest planes. These two would have high values for their "sweep factors," and at any given angle of incidence good "lifts."

Some Considerations on the Plane Cross Section and Form.

The advantage of a thick plane with suitably shaped entering and leaving edges has already been mentioned. It has also advantages from the point of view of the stability of the machine. During the past year the writer carried out a series of experiments with models of 30 ins. in span and 6 ins. chord, approximately $\frac{1}{12}$ scale of a full-sized machine. Several planes were made of curvatures varying from a flat plane to 1 in 6. They were weighted with lead and weighed from $\frac{1}{4}$ to $\frac{1}{2}$ a pound each, being constructed of tracing cloth stretched on a No. 17 wire framework, the latter fixed on a central spar. They were tested as gliders in winds of varying strength. It was found that with equal weight and area the planes of small curvature flew equally well as those of deep curvature, and single surface provided a vertical fin was fixed on the central spar. The gliding angle of the single surface deeply curved model was poor compared to that of the small curvature plane, and this was not improved until the lower surface was filled in. The results then were the best obtained.

It would appear that with a gradual thickening of the curve towards the centre, the equivalent of central vane is obtained, and that lateral oscillations are damped out by it, as with the vane on the other plane. This, however, trenches upon the subject of stability with which the present paper does not deal, and it is on considerations of centre of pressure movement that the plane design should be based. It is for these reasons that a varying angle of incidence along the plane span, and a set back wing is an advantage.

A plotting out of the stream line distribution round a curved plane in motion through the air would confirm these experimental results. A tracing on Fig. 15 of one of Eiffel's

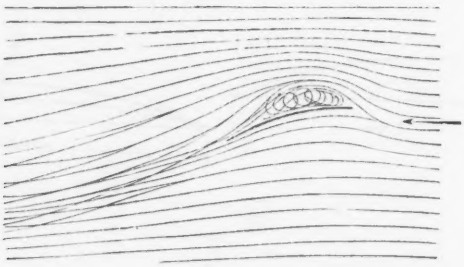


Fig. 15. *Block by "Aeronautics."*

diagrams shows the stream lines rising up at the front edge of the curved plane, forming a turbulent region on the top which might be filled in as shown, and give a more efficient result. The procedure is analogous to that of fitting a tapering body fore and aft of a square plane to diminish its resistance by converting it into a stream line form.

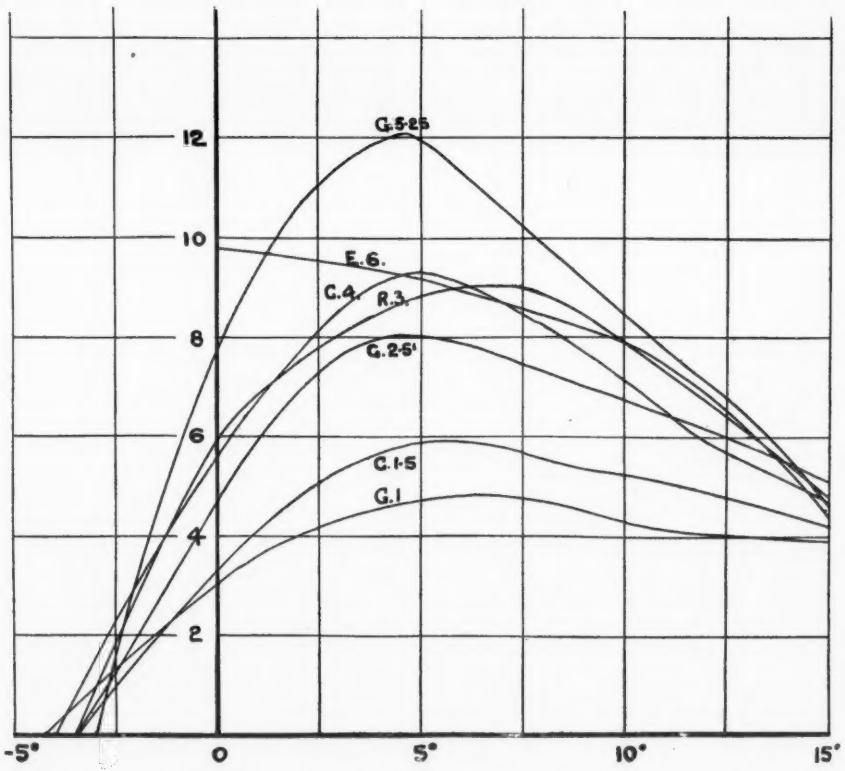


Fig 11

R $\frac{1}{20}$

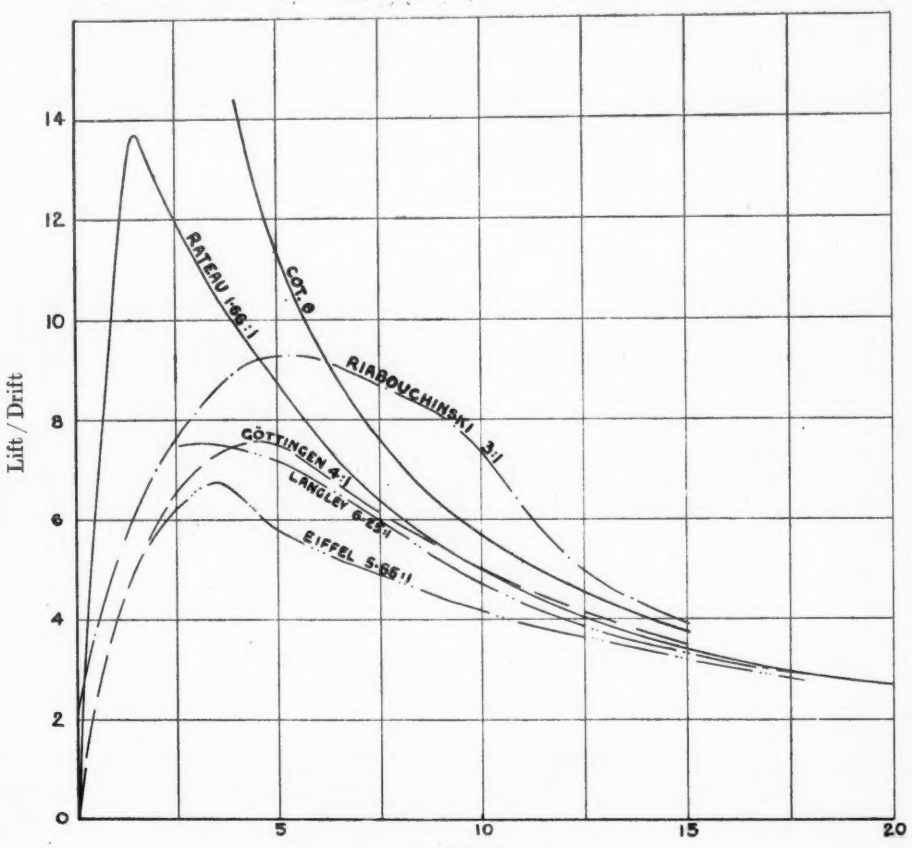
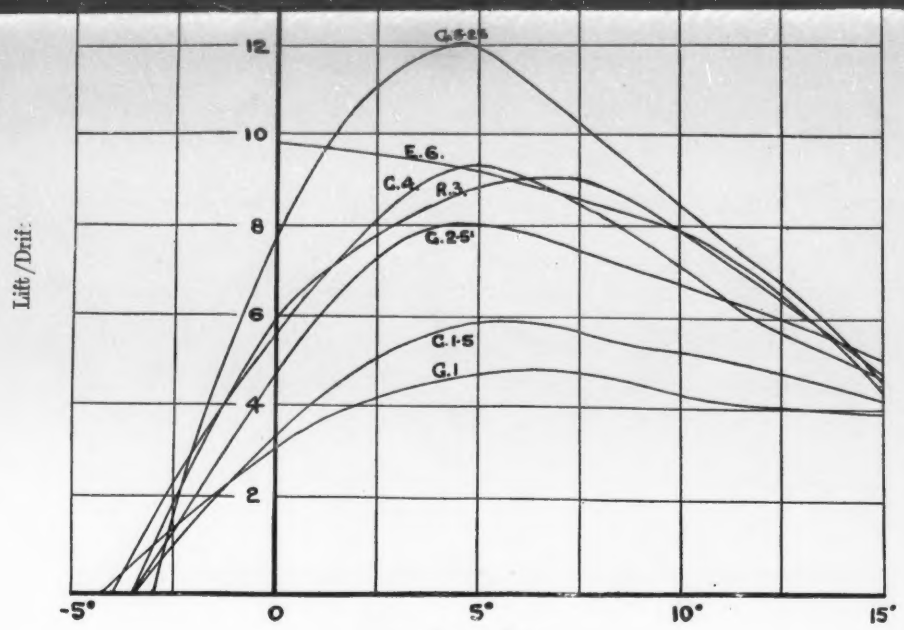
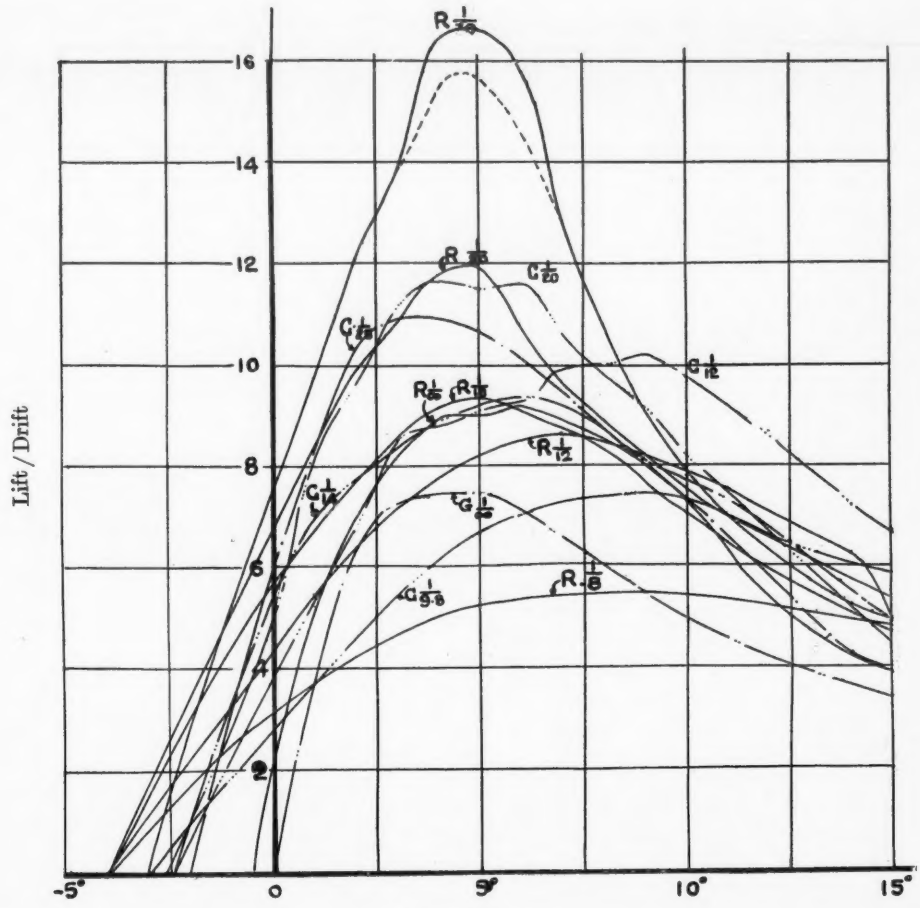

Lift / Drift
14
12
10
8
6
4
2
0
5
10
15
20
RATEAU 1·96 : 1
COT. 8
RIABOUCHINSKI 3:1
GÖTTINGEN 4:1
LANGLEY 6·25:1
EIFFEL 5·65:1
Angle of Incidence

Fig. 10



Angle of Incidence
Fig 11



Angle of Incidence
Fig. 12

FIG. 13

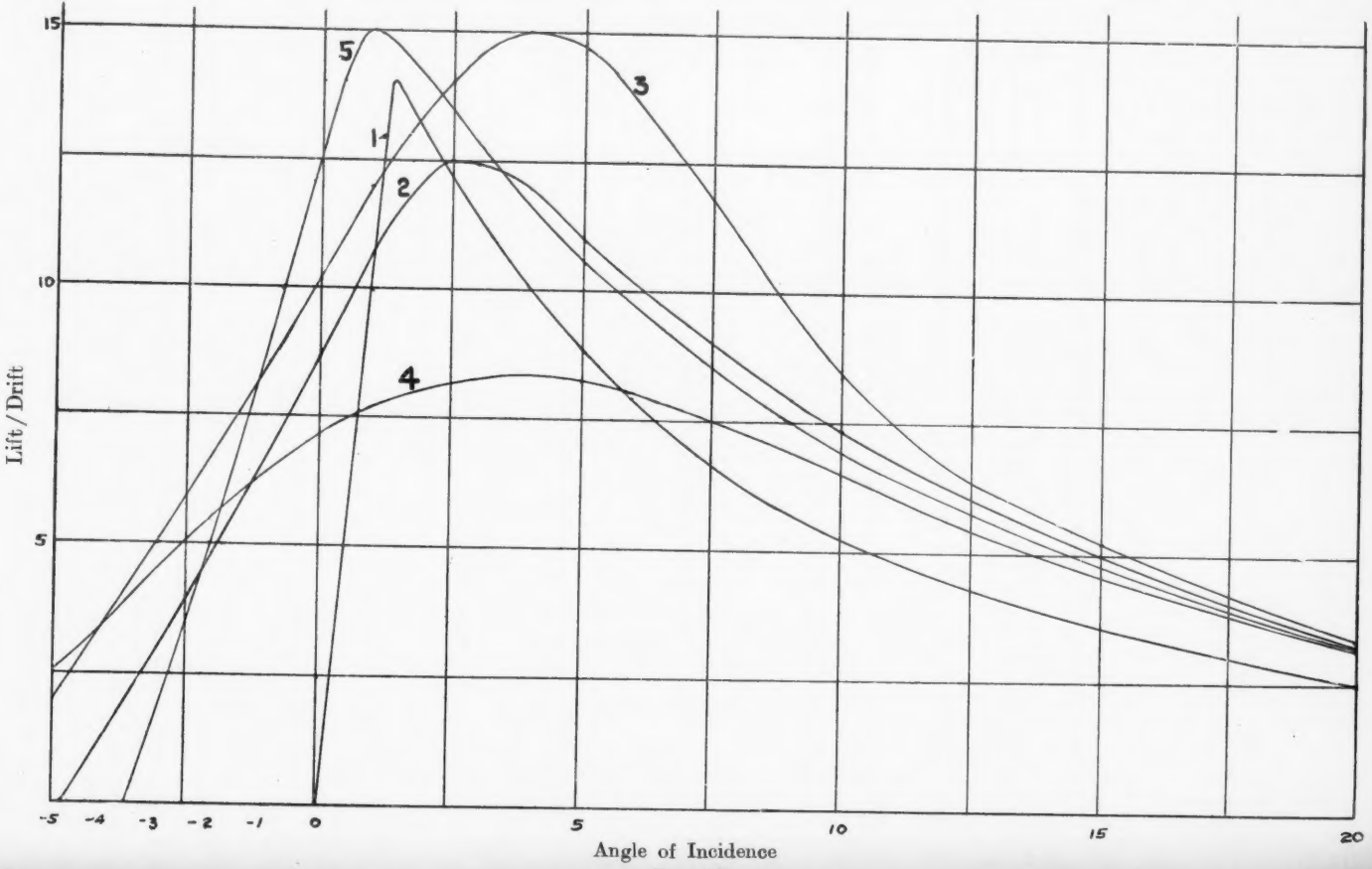


Fig. 13

The various lift and drift curves in Figs. 10, 11, 12, and 13 bear out the conclusion generally set out above. The higher the aspect ratio the better the lift to drift ratio, but if deeply curved planes are used the under surface must be filled in to preserve the efficient properties of the lightly curved ones. From every point of view the well-known conclusion is arrived at: make the planes with as large an aspect ratio as possible. The lift and drift of planes such as these can be calculated by considering each element of the plane by itself and applying to them the data given above.

Experiments on planes of varying plan, form, curvature, and dihedral angle, are greatly needed to give further data for design work. It is only by improvements in lifting power of the planes and an increase in the "lift and drift" ratios that progress can be made. It is for experiment to show how this may be accomplished. Even now it is well known that the power required for actual flight is comparatively small, but the accleration problem involved necessitates the carrying of large and heavy engines which, if the machine were lighter, would not be required. Lightness can only be obtained without sacrificing strength by improvements in the qualities of the sustaining surfaces, and to improve these it is necessary to experiment, experiment, experiment.

In conclusion, the writer would tender his best thanks to Mr. C. W. Meredith for his assistance in the preparation of the curves and data, and also to Mr. A. D. Jones.

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DISCUSSION

The PRESIDENT: The extremely interesting and valuable information—to me somewhat abstruse and difficult to follow in detail—should I think be of very great help to many here and many who are not here, and it will very pleasing to us to have a prolonged discussion on this interesting paper. I am sure you must have a great deal to say.

Mr. A. E. BERRIMAN: Mr. Chairman and Gentlemen, it is with diffidence that I attempt to discuss a paper so abstruse, but I can at least acknowledge my appreciation of the extremely able and lucid manner in which the author has dealt with a difficult subject. It relates to a side of aerodynamics in which I am deeply interested and as Mr. Handley Page's method of investigating the problem appears to differ somewhat from my own, it is only natural that I should enquire whether it results in the same general solution.

Taking formula 9 as a basis of investigation, I think that this might be evolved from fundamental principles in the following brief steps:—

(I) $P = m f$ (where P = lift, m = mass of air deflected, f = acceleration of mass downward)

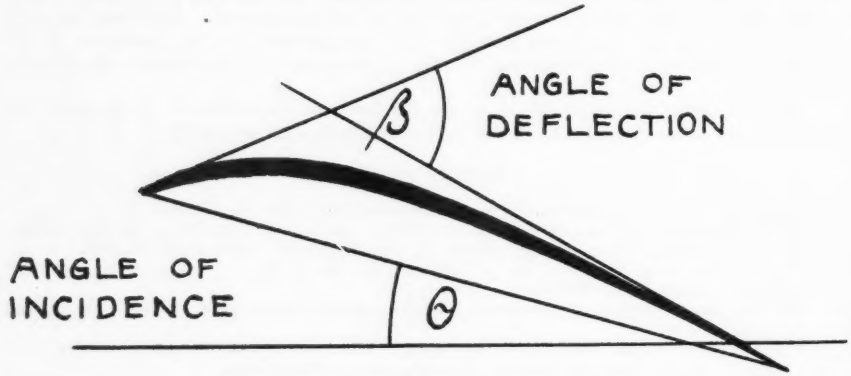
(II) $m = S\frac{w}{g}AV$

(III) $f = Ve$

(IV) $P = S\frac{w}{g}AV^2e$

It would appear, therefore, that so far as the working formula for lift is concerned I am in accord with the author and may therefore pass on at once to a consideration of the sweep factor, which is really the gist of Mr. Handley Page's paper.

The sweep factor itself has been deduced by Mr. Handley Page from a compound factor involving the angle of the planes, by taking the effective angle as that represented by the angle of incidence, that is to say, of the chord to the horizontal. The result has been to deduce very high values for the sweep factor; indeed it might be argued from the data given this evening that biplanes should have a gap about three times what they have at present. It is, however, on this detail of angle that Mr. Handley Page's line of thought and my own appear to diverge, for I am very much in favour of adopting as the effective angle of the plane an angle that I have termed the "angle of deflection," which is measured at the point of intersection of two tangents drawn to the entering and trailing



edges of the planes. Such an angle may be quite easily three times any ordinary angle of incidence at which cambered planes are used in practice or tested in experiments, and the mere introduction of angles of this order into the equation would at once reduce the sweep factor itself to a value in the order of unity, which, so far as can be seen from practical results, is approximately correct.

My object in thus comparing results is not so much to advance my own line of argument against that of Mr. Handley Page, however, as to emphasise the necessity of a thorough series of experiments being carried out for the express purpose of determining the sweep factor, the effective angle of a cambered plane, and the influence of aspect ratio. It has always seemed to me extraordinary that so much time has been spent on experiments with flat planes; and now that it is generally accepted that the cambered planes is not merely a curiously efficient form of flat plane but represents a fundamental principal in aerodynamics, it is to be hoped that cambered planes of practical shape will soon receive the attention that they deserve in laboratory work.

Mr. R. à C. Beadon: The remarks made to-night have corroborated the experiments that I have been making during the past twelve months with regard to the depth of the camber. I made a model, a triple biplane—all the planes are in the same plane or in parallel planes—and I understand that that would be the best position for the plane to enter the air from what we have heard to-night. For instance in flight parallel to the ground, my cambers will be like that, going forward (demonstrating), and in the model I reckoned up that I got 11½ ounces to a square foot driven by two twin propellers which had 6¼ ounces of rubber. I think that is very heavy for a model.

Mr. F. Handley Page: What speed?

Mr. R. à C. Beadon: I couldn't tell you.

Mr. Handley Page: Of course the lift you would get depends entirely on the speed.

Mr. R. à C. BEADON: It was a model driven by 2 twin propellers, and each 18-inch propeller had 6¼ ounces of rubber. She had pretty good speed because I flew the same model up at Coventry in the gale which was acknowledged to be going more than 40 miles an hour, and the machine was well under control the whole time.

Mr. HANDLEY PAGE: Travelling forward against the wind?

Mr. R. à C. BEADON: I started facing the gale, and she shot up like a rocket about 60 feet, turned round at broadside to the wind, circled right round, faced the gale, and came back. Then I took her and started her at right angles to the gale so that she got it broadside on; as she left my hands she turned over like a yacht at an angle that much (demonstrating), slid clean round, ran before the gale, came back into the gale and when she was about that much (demonstrating) off the ground, one of the rubbers got underneath the wire which was too close to it, and locked one of the propellers dead. In spite of this she made her circle in about 3½ times her breadth, and then came down. I have great faith in the use of a large camber, and that is why I have in my patent protected myself on the use of one sixth of a circle up to half a circle. I have models with one third of a circle and one fourth of a circle, and in my plane, every plane is either on the same plane or in parallel plane, and not with any elevator, and I do not think there is another model anywhere in the world that I have heard of on the same lines. She is a beautiful flier: she flew 104 yards on Clapham Common.

A VISITOR: I should like to make just a few remarks on some of the interesting things that Mr. Handley Page has told us to-night, and one thing is the efficiency of a thick plane. I think there is a good reason for that because what plane is more efficient than a bird's wing? You will find in a bird's wing the thickness is about one-tenth of the chord, and actual experiments and calculations made have shown that most planes are most efficient when they have those proportions. With regard to the very interesting remarks that Mr. Handley Page made just at the conclusion of the lecture, they bring forward some very interesting things about the horse power required in actual flight. He says that only small horse-power is required, but it has to be great on account of the great weight of the machine. Now I think that the weight of the machine does not really matter because the dynamic resistance is really small compared with other resistance, so that the tendency now is to have great heavy machines with good lifting capacity, and that brings us to the point of how much real horse-power is developed upon actual flight. Now aero engines are described with fifty or sixty horse-power, but I question very much whether they are given more than half that. I may say that I am at present experimenting with an aero engine said to be 30 horse-power, but with most careful tests, and the best tuning up, I get only about 18 horse-power.

Mr. T. W. CLARKE: I should like to associate myself with one of the previous speakers in saying that I consider we have an extremely valuable paper, and I should like also to thank Mr. Handley Page for the ability with which he delivered it. I understand from what I have heard that there are still some very interesting experiments to come later on. There is one point in the matter of thick surfaces. I should like a little information, in the last diagram I think it was, as to what the actual curvatures were in those particular curves. I did not quite see it—the one with the two thick planes as well as others—as to whether they were all of the same curvature, and in the case of the thick planes, was that curvature measured along what one might call the medium line. I think it is very often the case that one measures only the top surface or the bottom surface, and takes that as the curvature. The only proper way I can see is to measure the curvature along the centre line. I cannot conceive that theoretically in a thick surface you have, by reason of its thickness, a greater value than a thin surface conforming exactly to he stream lines, but practically of course, it is quite possible in order that it may maintain its shape a little bit better or some reason of that sort. Take a plane 1 in 14 with the back 1 in 14 and with the face say flat, it would be only equivalent in its mean curvature to a flat 1 in 28 which, as Mr. Handley Page has pointed out, was very near to the curvature of 1 in 30 which has been shown to give very good results. I daresay Mr. Handley Page will be able to give me that information about the thick planes (applause).

Mr. B. G. COOPER: I should like to thank Mr. Handley Page for his most interesting lecture. He is to be congratulated on having evolved a formula which agrees with experi-

mental results—it is not everybody who does that. I think he was right in insisting upon the fact that it is purely an empirical formula, it is only evolved for the purpose of reducing his experiments upon practical machines to some sort of form. I do not think he claimed that it was really based upon any fundamentally accurate conception of the flow of the fluid stream. In the case of a flat plane at positive angle of incidence, the entering edge not being tangential to the stream, there is added resistance, due to the "shock" when the impinging stream is divided on the front face of the plane. This resistance adds both to the lift and the drift, to a degree which Mr. Page's excellent formula enables him to compute very exactly. In the case, however, of a properly curved plane (such as a Phillips section plane) at an appropriate speed of flow to the angle of incidence of chord, the plane enters the stream tangentially, and there is no "shock." The stream divides, not on the front face of the plane, but opposite the front edge. The added proportion of lift and drift which previously existed seems to me not to exist in this case, and Mr. Page's theory would appear to need bringing into accord with the altered conditions of flow. Mr. Berriman's theory does not require "faking" in the same way, as it was invented to apply to properly cambered planes only. When Mr. Page has added the necessary constants to his formula it may be that the differences between the results it gives and those given by Mr. Berriman's formula are no greater than those between Tweedledum and Tweedledee. From a rule of thumb point of view Mr. Page may therefore justify the application of a formula containing certain factors to a phenomenon where these factors do not in reality apply. Theoretically, however, the procedure is not justifiable. It seems to me, therefore, that although Mr. Page's theory is most accurate and valuable in the case of a flat plane, it is open to the objection, when applied to a properly cambered plane, that it is not basically accurate in conception.

Mr. F. Handley Page in reply said: I was very much interested in Mr. Berriman's remarks. I have already had numerous discussions with him on this very point, but I do not know that we arrived at any particularly tangible result. Briefly the point is this: you have a horizontal velocity to start with and a velocity parallel to the plane to finish up with. These velocities are practically equal, and if you complete the vector diagram you will find that the change in velocity is equal to the final velocity multiplied by sine of the angle. Now in Mr. Berriman's theory—which so long as it agrees with the results is every bit as good as any other, because that is the only standpoint from which you can judge them—you take the horizontal velocity to start with, and consider the air as travelling a distance equal to the projected length of the chord on a horizontal plane. At the same time the air has to travel downward an amount equal to the projected length of the chord on a vertical plane. The ratio of the two lengths, which Mr. Berriman takes as the ratios of the two velocities, is tan θ. The more correct way, in my opinion, is however, to complete the parallelogram of velocities and find the change in velocity by the method indicated in the paper. After all, as he says, it is only a minor point whether you take tan θ or sin θ because both, in the small limits of angles which are used in ordinary aeronautical work, are equal to the angle in radians. The result therefore is practically the same, and it does not make any difference whether the air is moving against the plane or the plane moving against the air. There are some people who will tell you because the plane moves through the air you get an entirely different result from that when the air moves against the plane, but candidly I cannot see that there is any difference; the only point in which there may be any difference at all is due to the character of the wind which is blowing against the plane. If you have a perfectly still day, the air through which the plane moves is perfectly calm, but if you have a wind blowing against your plane the character of that air is very complex and it is quite possible you may get different results. It is quite to be anticipated when you get your plane out in the air and fly that the results will not agree with the wind tunnel experiments because of the complex character of the wind.

The next point he raised was with regard to the lift to drift formula in which he says $\frac{\theta}{\theta^2}$ squared comes to a value of $\frac{1^2}{\theta}$ I think if he will turn to the formula he will find that this result is exactly what you obtain if you do not take into account the other

resistances. You will see that the drift in the formula No. 10 has a θ^2 turn in it and the lift has a θ term. These theoretically are the total resistances and the total lift, so that the one over the other is $\frac{\theta}{\theta^2}$ or $\frac{1}{\theta}$. The curve of lift to drift for flat planes giving co-tangent θ was plotted so that you can see how the theoretical and practical results agree with one another.

He rather objected to the use of the flat plane as the results are of no practical bearing. My object in using a flat plane was to get a basis on which to work out results. I did not at all mind whether it agreed with actual theory. All I wanted was to get a formula which would agree with the past results and which I might count on being correct in any future design I might wish to work out. I took this method in preference to the formula which Mr. Berriman suggests, because I think it represents more fairly the true state of affairs. Mr. Berriman would calculate the lift by the total angle through which the air has been deflected, firstly considering its de-acceleration from a rising to a horizontal current and then from a horizontal to a downward current. It seems to me that the entering front edge is only a kind of transformer. You let your air out from underneath the front edge, it flows upward from the point of division and you lose a certain amount of lift. This you get back again at the top, and whether you get an efficient or an inefficient plane depends on the efficiency of your transformer in the front. It has always seemed to me that the rising current that you get is not due to some mysterious property of the plane which imparts its influence before the air reaches the plane. You cannot imagine mysterious feelers tanding out and exerting their influence in front of the plane, causing the air to rise upward toward the plane in a kind of adoration. I think the only reason why you have your rising current in front of the plane is due to that deviation taking place and an upward momentum being imparted to the air. You get the lift back again on the top of the plane. That is the reason why a curved plane is more efficient than a flat one because you have a more efficient transformer.

There is another reason why I do not like Mr. Berriman's formula. With it you get a constant lift no matter at what angle you incline your plane. Supposing I have here a curved plane. There is a certain angle between the tangent to the front edge and the horizontal, and also between the back edge and the horizontal. The sum of these two angles of deflection remains constant. For the front angle is made up of the angle between the chord and the tangent minus the angle of incidence for the front edge; the back angle is the angle between the tangent and chord plus the angle of incidence. If you add those two together you get twice the angle between the tangent at either edge and the the chord. No matter therefore what angle you use you would always have the same lift. Of course, one way of getting over that, and I think it is the right way if you use that formula, is to say that you always choose a curvature which is appropriate to the angle of incidence you employ and the formula only applies to this case. If the angle of incidence is altered the curvature proper to it is altered. This formula you will thus see does not give a complete or accurate relation for the variation of lift or drift as found by experiment.

This leads me on to the next point in regard to the sweep factor including some constant of the angle. This probably is quite correct. If you have a 6 to 1 plane as in a Wright Machine and a sweep factor of 3, you would get a tremendous amount of interference unless the stream line distribution due to each plane in some sort of manner helped each other which I do not think likely. Very probably there may be a greater angle of deflection than the angle of incidence that we take as the angle of deflection. As to that point I am not quite certain; one cannot tell because the factors are all involved in the same constant and therefore is very difficult to determine. The main thing you find from the curves is that with varying angle the pressure goes up on a straight line law.

Lastly we come to the old question of skin friction which has been raised very many times. It is a small factor in comparison with the body resistance of the plane. The irregularities in the surface of the plane even if you smooth it are great. The pits in the aeroplane—if I may term them so—are big compared with the air particles and are likely to cause eddy disturbances of the air which will be very great compared with what one may call skin friction proper. To measure skin friction you have to cut out the body

resistance somehow and the allowances to be made are so great in comparison with the dimensions of the factors to be measured that the results are not satisfactory. All I have done has been to take the results at zero, body resistance and skin friction all in one, and rest content with that, not troubling as to whether it was skin friction or body resistance, but taking it as a total.

I was very interested in Mr. Beadon's experiments with his plane. I am quite convinced myself that a deep curvature plane—although not too deep—offers a great many advantages.

Another gentleman raised the question of a bird's wing, and this is an important point. There must be certainly some reason in nature for every bird having practically a deep curvature wing, although I would not say that because a bird has a deep wing therefore make the planes deep. The bird's wing was the first thing that suggested making a plane deep, but unless I had some scientific proof, some figures on which I could show that there was an advantage in so doing I would not use a deep plane. If I found, and every experiment showed, that a thin plane were better, then there must be some other reason, either for the folding up of the bird's wing; there must be some reason for the deepness of the plane rather than an aerodynamical one. There is then the question of the weight of the machine. While the weight does not make much difference if you have an efficient plane, it comes into the question when you want to accelerate—it takes power to accelerate it. It is the same reason why an ordinary motor car to carry 4 to 5 people has at least a 12 HP engine and two good old horses will do the work. The difference is in the acceleration problem. If when driving you see a man with a car about to run you down you get out of his way. It depends on the horse-power of your engine whether you are able to do so quick enough. If you have a light aeroplane and come to an air pocket, you can get out of it quicker because your weight is less, and the power required to accelerate is less. That is the reason why if one can reduce weight it is an advantage.

To turn to the question of engines. There are some engines that are rated at their right output and—there are others. The 50 horse-power Gnome engines I believe give about 40 horse-power from Mr. Lanchester's tests. In regard to the gentleman's experience of a 30 horse-power engine giving him 18: I have had similar experiences myself and the horse-power has not always reached 18.

Mr. Cooper raised a question about a Phillips section and the theory given in the paper falling to the ground. It still holds good for this. The main principle is this: whenever you have air impinging against a surface inclined at an angle to the air, the stream divides into two parts. Wherever there is a division there must be an upward and downward flow. To get an efficient plane the division should be at the point where the front of the plane is. There is then no backward effect underneath the edge of the plane. If the curvature is too deep underneath the plane becomes inefficient. It would be quite possible, if one were to extend formula a little bit more and look into it a little closer, which I have not done up to the present, to calculate the constants for those particular sections.

Mr. Clarke raised the question re Rateau's last experiments. All the curvatures I have given you are the mean curvatures between top and bottom. In the case of the Rateau planes with a smaller curvature and thin planes, they were not so deep as the thick planes. Part of the reason I think for the efficiency of the thick plane is that the top air stream merges with the underneath air especially if it is gradually brought down in its curvature at the back. It then more clearly comes parallel with the underneath stream and you get less disturbance at the back. As regards the other point as to whether one ought to correctly take the mean curvature it is very difficult to say. One knows so very little of curve planes, and there have been so very few experiments carried out, that it is very unsafe to hazard any opinion except of what has actually been done. The main thing I think that the study of the present experiments shows is the lack of adequate experimental knowledge. It is only by experimental knowledge that one can get ahead and be able to dogmatize as to what you can do in the future. Without that you can only speculate and everyone has as much right to their opinions as myself, and therefore they can probably form conclusions quite as correct as any that I should give them.

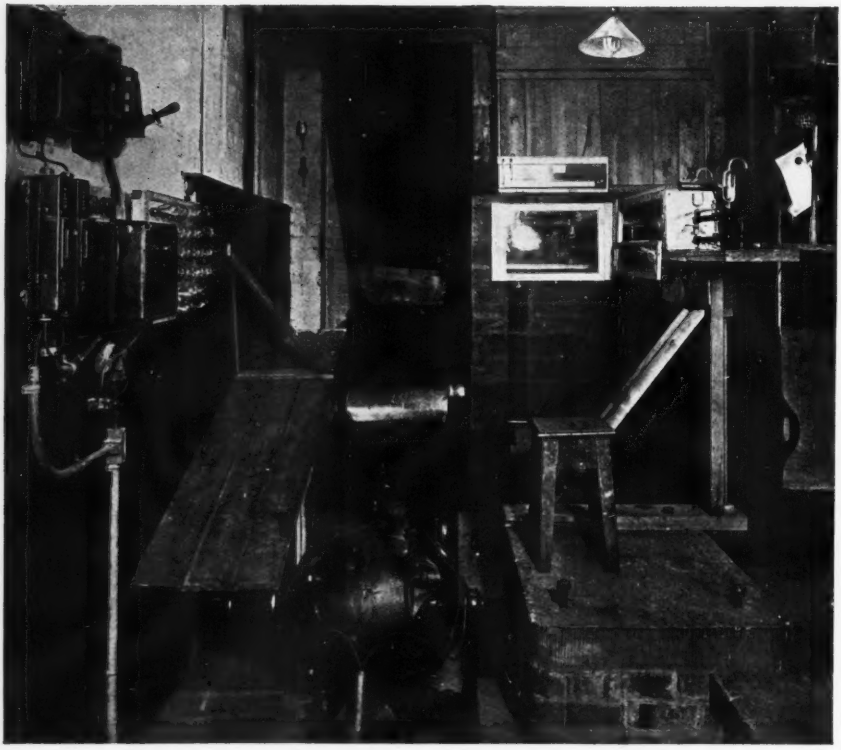


FIG. 12

SIDE VIEW OF WIND TUNNEL

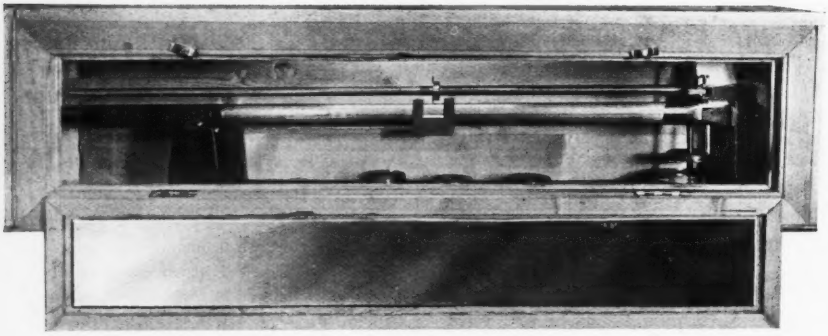


FIG. 13

THE BALANCE AND CASE

REPORT

Presented to the LABORATORY COMMITTEE of the AËRONAUTICAL SOCIETY, on THE WIND TUNNEL ERECTED AT EAST LONDON COLLEGE.

Walter F. Reid (*Chairman*).

B. G. Cooper.	Mervyn O'Gorman.
R. M. Balston.	F. Handley Page.
A. W. Isenthal.	G. P. D. Saul.
A. P. Thurston.	T. O'B. Hubbard (*Sec.*)

ONE of the first researches proposed by the Laboratory Committee of the Aëronautical Society of Great Britain was upon the resistance of bars and wires in a current of air.

The apparatus being used for this purpose is shown in Figs. 1, 2, 3, 12 and 13. It consists of a specially modified vertical wind tunnel, erected in the Aeronautical Laboratory of East London College (University of London). This apparatus is in the main similar to that used by Dr. Stanton at the National Physical Laboratory.

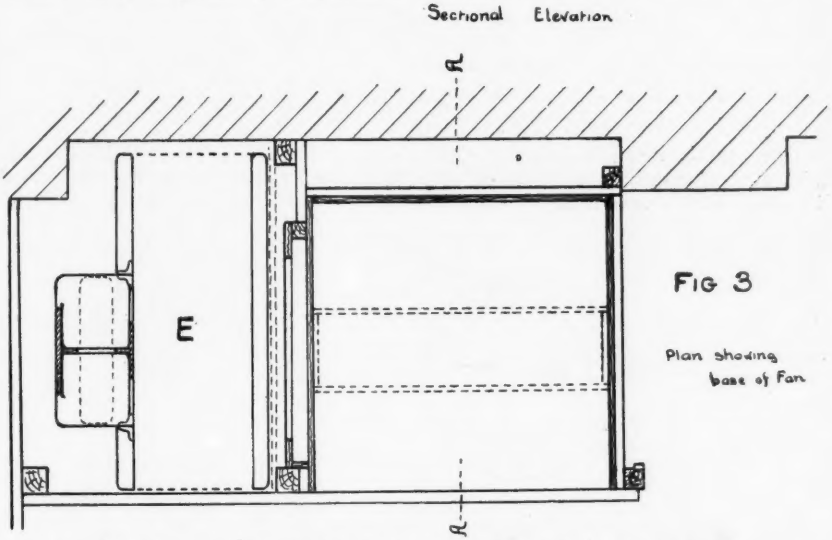


FIG 3

It consists of a rectangular test tunnel A, 4 ft. × 1 ft. and 6 ft. long, passing through the ceiling and terminating in a rectangular box 4 ft. square and 6 ft. high. This box may be extended upwards so as to form a wind tunnel having a cross section 4 ft. square. The upper portion B of the box, is partitioned off and is provided with a short rectangular tunnel C aligning with the tunnel A. The lower portion D of the box is in communication with the suction side of a 25 in. Keith Fan E, by Messrs. Keith and Blackman, bolted down to concrete foundations at the side of the tunnel. The outlet F from the fan is connected to a hole in the ceiling. The air is drawn from the room above, into the tunnel A, and is returned through the outlet F, without entering the laboratory and inconveniencing the experimenter. The upper portion B is provided with air tight glass doors or slides, to facilitate observation. An air tight glass case G is mounted at one side of the portion B upon an independent table I, and is adapted to contain the special weighing beam H. This beam is described in detail later. One side of the lower portion D is removable to allow free entry to the tunnel and the fan. The upper portion of the tunnel A is flared out to assist the entrance of the air, and to avoid a *vena contracta*, and a suitable gauze is mounted at *a* and *b* to ensure a uniform current. The tunnels A and C are in the position shown in the figure when measuring the resistance of beams, and at right angles to this position when measuring the resistance of wires.

The fan is provided with a 25 in. pulley, and is driven by a 5 in. belt from a 6½ HP 480 volt motor, lent to the Laboratory Committee by Mr. A. W. Isenthal. This motor runs at about 2,000 revs. per min. at full power, and is provided with a 6 in. pulley. It is controlled by a special lamp rheostat, so that the speed of the fan and of the air current may be varied to any velocity up to the maximum velocity. Special precautions have been taken to protect the motor, notably by the provision of a Morris and Lister automatic cut-out switch in addition to the ordinary fuses and starter. This switch has a "time-factor" approximating to that of the motor.

The speed of the air current is measured by a Pitot tube as shown in Fig. 4. This consists of two steel tubes ⅛ in. diameter connected to a tilting water gauge. The tube A is provided with a thin lipped orifice facing the current for determining the dynamic pressure, and the tube B is formed with a brass tapered stopped end in line with the current and having four holes 1/50 in. diameter at right angles to the current for determining the static pressure. The difference between these two pressures is a direct measure of the velocity of the current of air, and is given by the following formula :—

$$V = 1{\cdot}03\sqrt{2gh}.$$

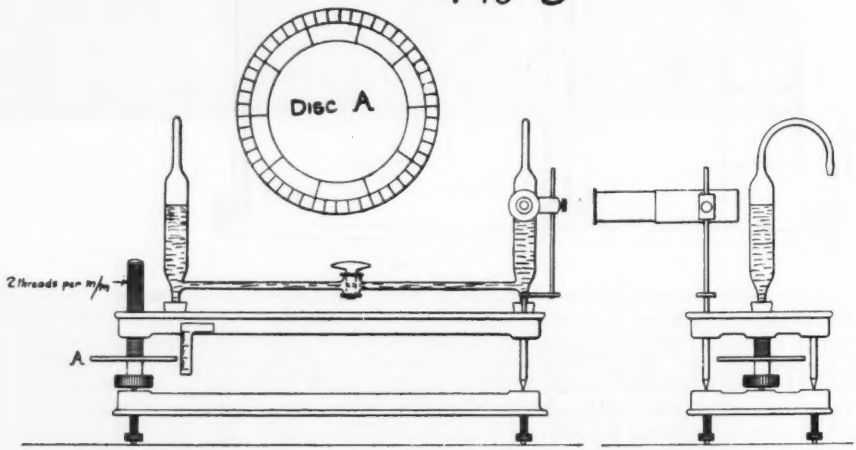
Where h is the difference of pressure in the two tubes in feet of air at the statical temperature and pressure of the air in the tunnel.

g is the acceleration due to gravity.

V is the velocity in ft. per sec.

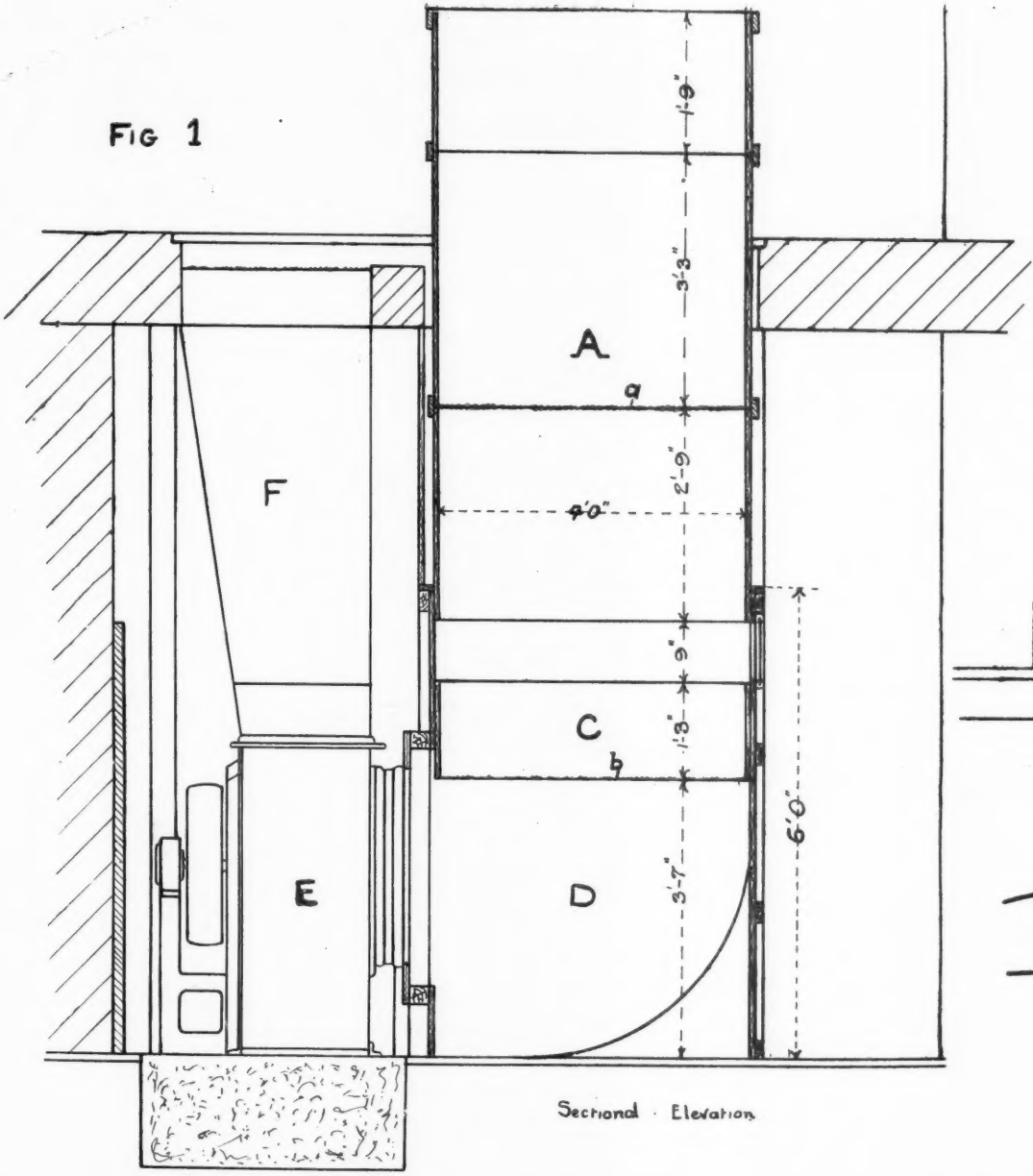
Dr. Stanton determined the constant of this tube by comparison with his standard tubes at the National Physical Laboratory. This tube is mounted in such a fashion that it can be readily moved to any point within the cross section of the tunnel.

FIG 5



The tilting water gauge is shown in Fig. 5. It consists of a U-tube having the diameter of the vertical tubes of a comparatively large diameter in comparison with the horizontal connecting tube, to prevent rapid fluctuations in level of the surface of the liquid. The difference in pressure between the two limbs is measured by tilting the gauge until there is no displacement of the water from its original position. By this means errors due to surface tension are obviated. The tilting is obtained by a screw having a pitch of 0·5 mm. and carrying a graduated disc which is divided into 50 divisions, so that one division represents 1/100th of a millimetre, or 1/1000th of a centimetre rise. The head of water so obtained is converted into the equivalent head

FIG 1



Sectional Elevation

FIG 2

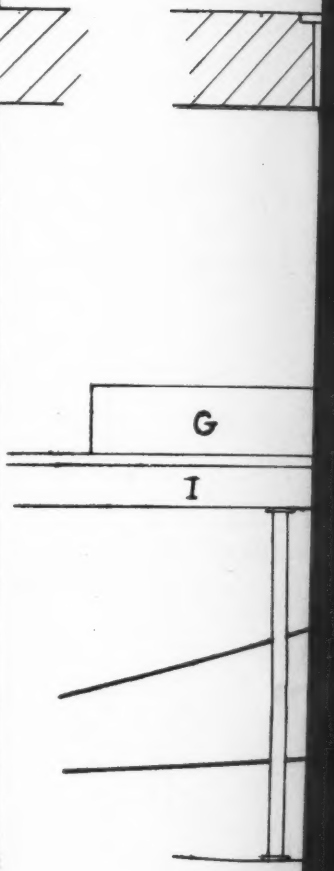
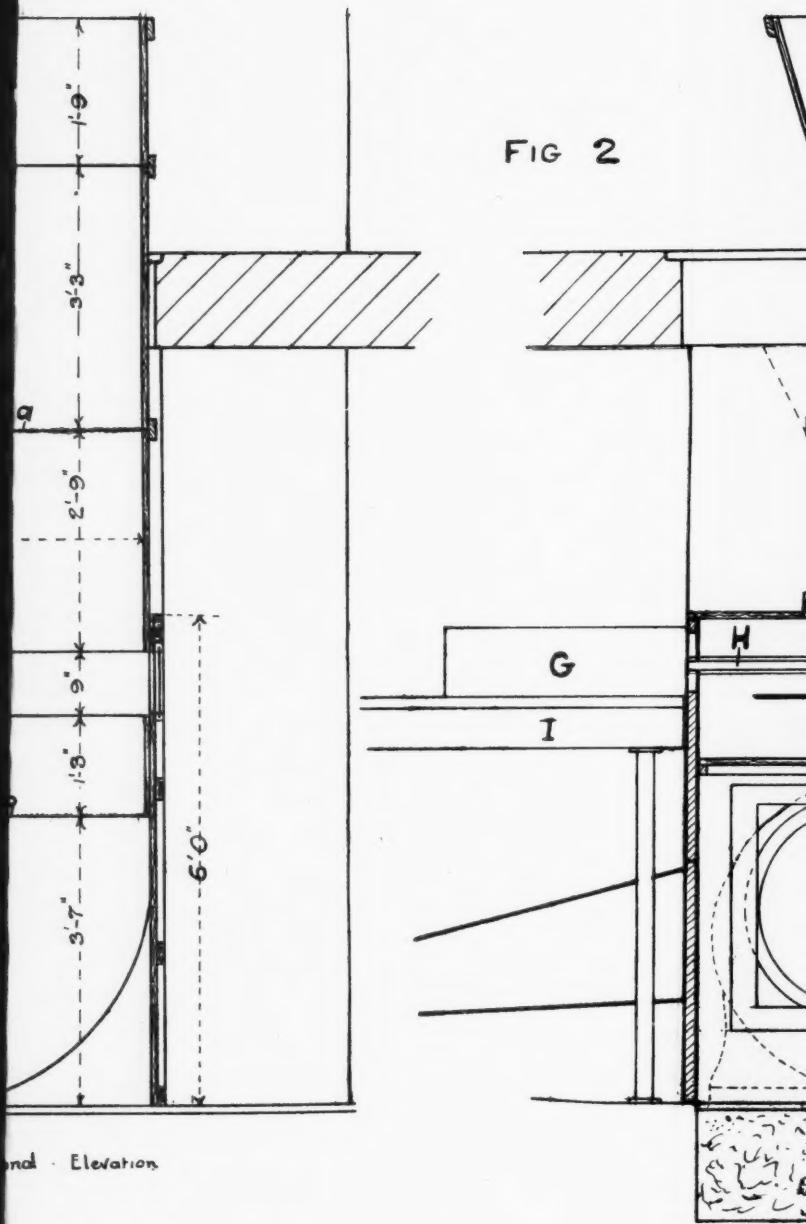
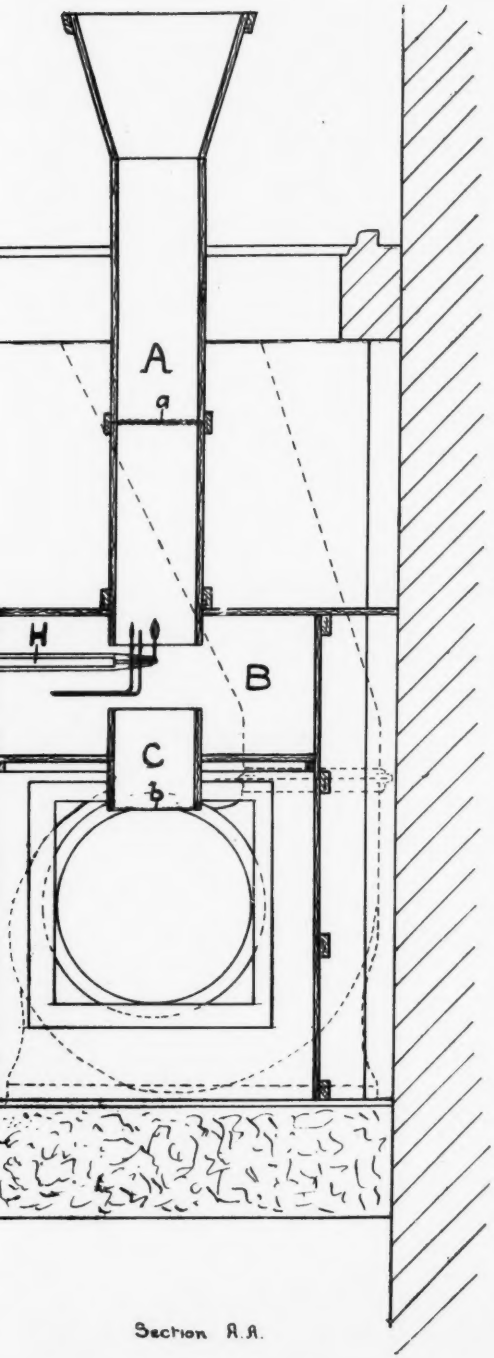


FIG 2



nal · Elevation



Section A.A.

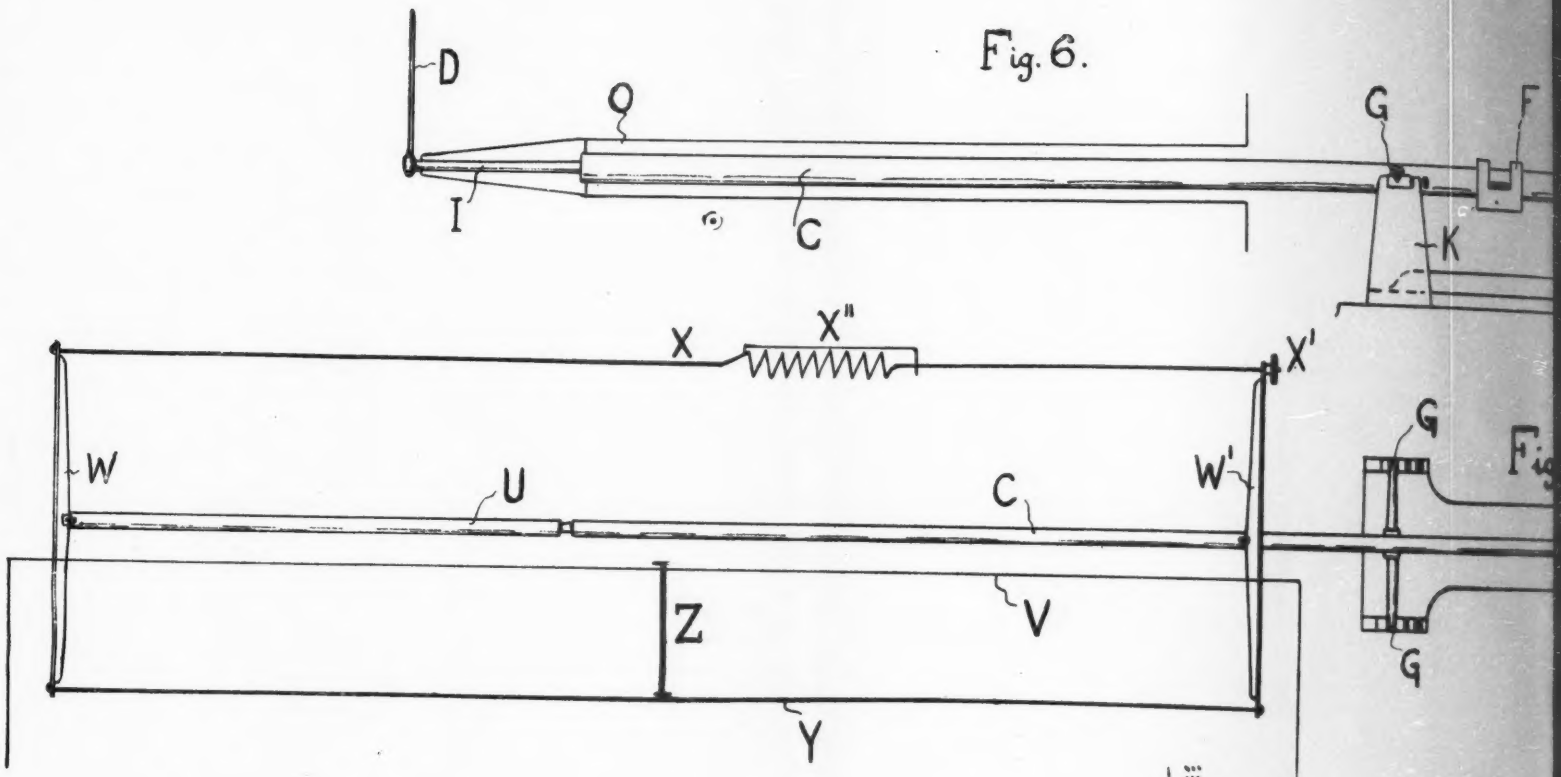


Fig. 6.

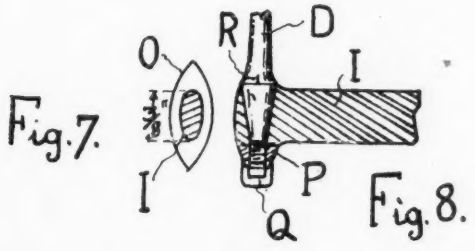


Fig. 7.

Fig. 8.

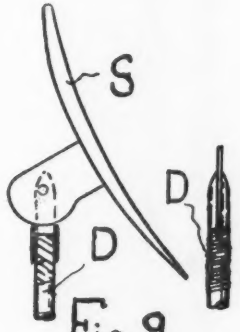


Fig. 9.

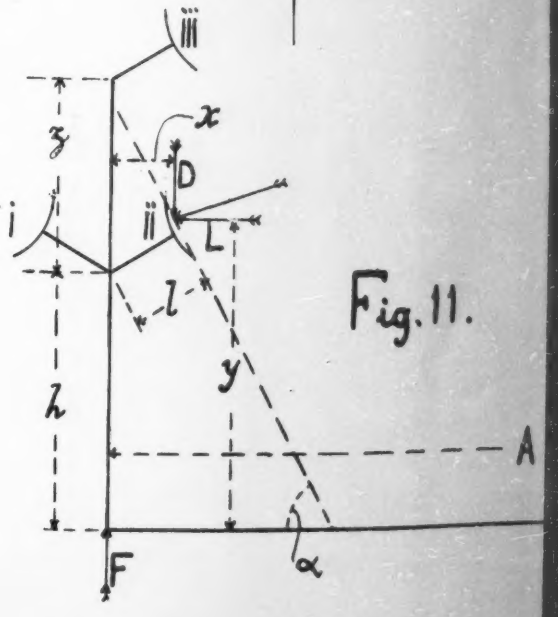


Fig. 11.

Fig. 6.

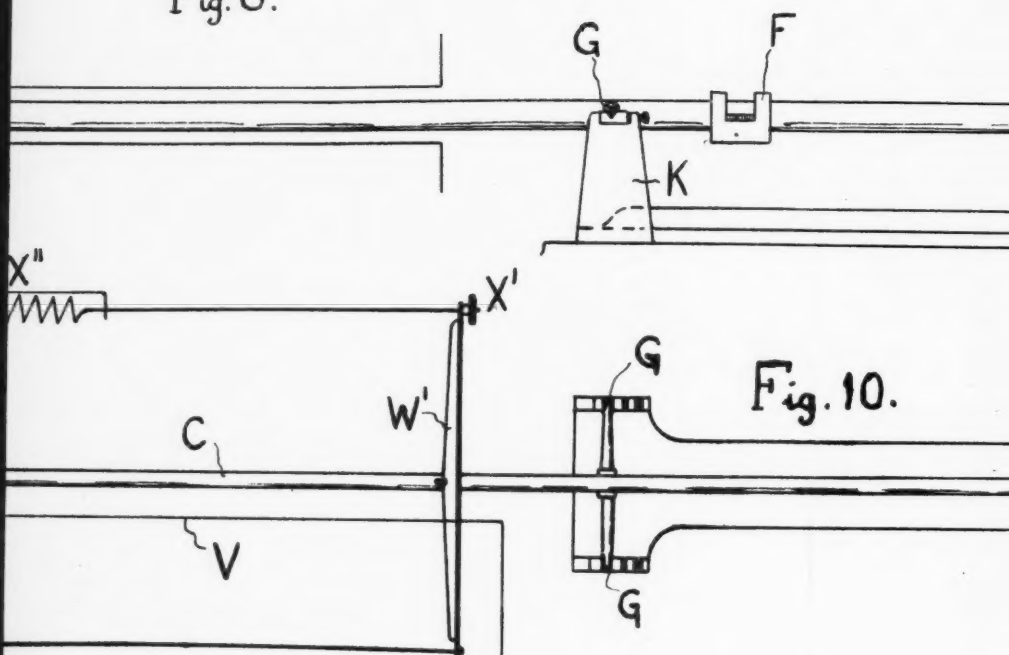
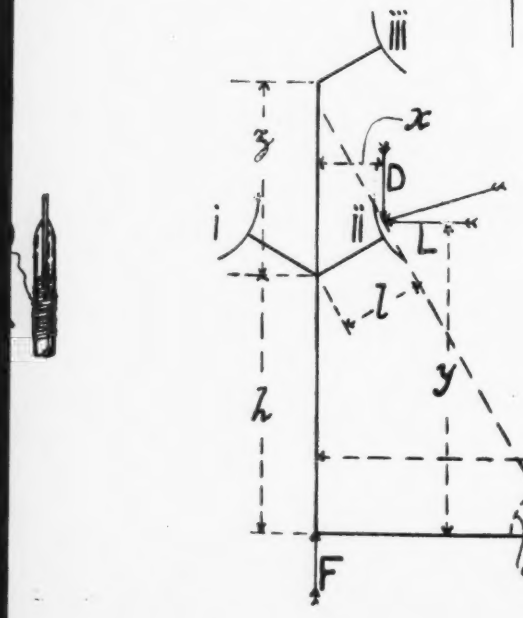


Fig. 10.



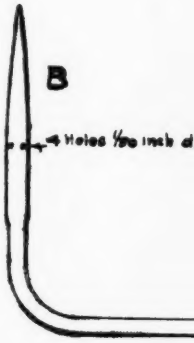
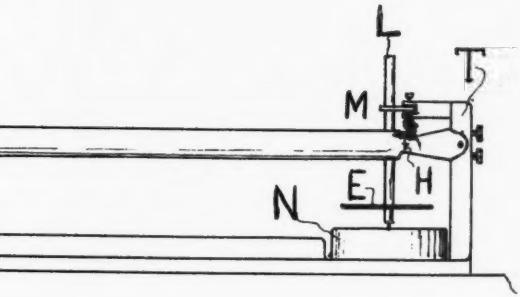


Fig. 11.



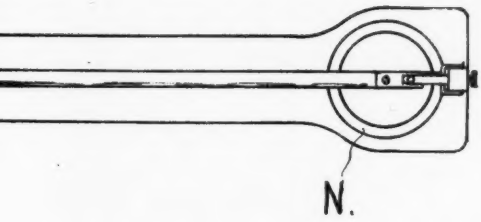
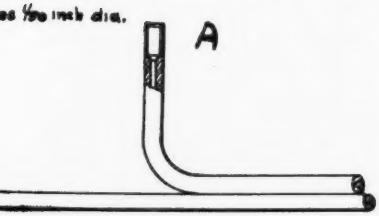
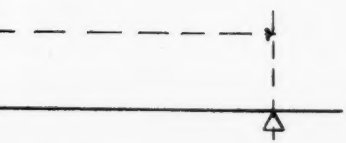


FIG 4





of air at the statical temperature and pressure of the air in the tunnel before inserting it in the formula $V=1{\cdot}03\sqrt{2gh}$.

A microscope is provided, having cross wires in the eyepiece for reading any variation or movement in the level of the water.

The Balance.

The balance was designed for use in testing :—

(1) The resistance of solid bodies, such as sections of struts.
(2) The lift and drift of planes of various shapes at various angles to the wind current, and also the centre of pressure of the resultant force.
(3) The resistance of vibrating wires, cords, &c.

It consists of a beam C, Fig. 6, about 5 ft. long, mounted on knife-edges G, on a cast iron frame K. At the end of one limb, an upright pillar D is mounted, about 3 ft. from the knife-edges, for carrying the test piece, and the other limb is graduated, and carries a sliding weight F, and a fixed upright bar L, on which are mounted a stop M, a plate E for balance weights, and a plate working in the dash pot N. The main portion of the beam C is of oval section steel tube, to make it as light as possible without sacrificing the necessary stiffness. The end portion I is solid, and removable, so that for some tests it may be replaced by an extension U shown in the plan. Fig. 10, of the beam. It tapers to a very thin oval section, as shown in Fig. 7, which passes through a wind guard O, to the centre of the wind tunnel. The wind guard, owing to the shape of the beam, can be made very narrow, and so causes no appreciable disturbance in the air current. As regards the pillars D, three were made, each capable of being mounted in the taper hole in the end portion I of the beam as shown in Fig. 8, and having a small nut P and thumbpiece Q to hold it in place. The contour of these parts was made as even as possible, to minimise the disturbing effect of the air current.

Two of the pillars are for use in testing planes, and are approximately 4 in. and 7 in. long respectively. Their upper ends are pointed and slit as shown in Fig. 9. The plane S to be tested, is mounted on a thin metal strip pivoted on a pin passing through the slit and clamped at any desired angle by a screwed sleeve. On opposite sides of the base of each of these two pillars are marks R, Fig. 8, which can be set against a mark on the beam I to indicate when the slot in the pillar is exactly parallel to the beam.

The third pillar is for holding symmetrical bodies, the resistances of which are to be measured, and it is pointed, screwed, and provided with two lock nuts, between which the object to be tested is clamped.

In order to give steadiness to the beam, the knife-edges are mounted 6 in. apart as shown in Fig. 10. The maximum swing of the balance, which must be kept very small in order to avoid error, is determined by two screws in the upright portion T of the frame engaging with the stop M. A graduated indicator at H shows when the beam is horizontal. The graduations on the beam are millimetres and centimetres, and as the sliding weight F has a vernier scale on it, ·1 mm. can be read, and ·05 mm. is easily estimated. The exact length of the outer arm of the balance is 35·95 in., and the weight of the rider or sliding weight F is ·24 lb. Therefore, every movement of the rider of 1 cm. means a difference in vertical pressure on the pillar D of ·002627 lb. A variation in weight of ·000013 lb. can thus be measured, and the balance is sufficiently sensitive to allow of this. The maximum increase in weight that is measurable by sliding the weight F, is ·18 lb. The beam is amply stiff enough to allow the use of a larger rider should that be necessary. A photograph of the beam is shown in Fig. 13.

Preliminary Tests and Corrections; Supporting the Balance.

Tests were made to determine what corrections would be necessary to allow for the distortion, under load, of the beam C and pillar D. In all ordinary cases, where the weight of the test piece is well below ½ lb., and its air resistance does not exceed ·13 lb., the errors are not ·1 per cent. from this cause.

The balance is mounted on a massive and strongly braced support, having concrete foundations, and not in contact with the wind tunnel, thus insuring the minimum of vibration. It is enclosed in a case with a glass door and the jockey weight is moved by an arm on a sliding rod, as is usual in chemical balances.

Testing the Resistance of Struts, &c.

A suitable length of the strut, or other symmetrical object whose horizontal cross-sectional area is not so large as to cause error in the tests through interference of the side walls with the uniformity of the wind current, is mounted between clamping screws on the screwed vertical pillar D, transversely with the beam C. In some cases it is convenient to mount the test piece on a strip held in the vertically slotted pillar. The beam is then balanced as nearly as possible by clamping weights on the disc E, and a final accurate adjustment is made by the sliding weight F, which should be near the pivots G when correct balance is obtained. The required velocity of air current is then applied and the beam again balanced as before, by sliding the rider F.

The air resistance in lbs. = (distance travelled by rider in c.ms.) × ·002627.

Measuring the Lift and Drift of Planes, and the Centre of Pressure of the Resultant Force.

For this purpose, it is necessary to make three tests with the plane at the required angle (α), see Fig. 11.

In the first test, the plane is in the position shown at (i), Fig. 11, and on the short pillar. In the second test, the plane is in position (ii), the pillar being turned 180°. In the third test, the plane is on the long pillar in position (iii). In all cases, the equivalent vertical force, F^{I}, F^{II}, F^{III} respectively, necessary for balance is found as previously described for struts.

The following values are then either known or can be measured, viz. :—

A = length of beam;
l = distance from the pivot centre of the chord b d;
h = height of the short pillar; and
z = difference in height between the long and short pillars.

It is desired to find the following values :—

L = the lift of the plane in lb.;
D = the drift of the plane in lb.;
x = the horizontal distance from the centre line of the pillar to the centre of pressure or point of intersection of the chord b d and the line of action of the resultant force; and
y = the vertical distance from the centre line of the beam to the centre of pressure.

Now $D\,(A+x)-Ly=F^{I}A$ (i);

and $D\,(A-x)+Ly=F^{II}A$ (ii).

$\therefore D=\frac{F^{I}+F^{II}}{2}$ (By addition from (i) and (ii)).

Again $D\,(A-x)+L\,(y+z)=F^{III}A$. (iii).

$\therefore L=\frac{A}{z}\,(F^{III}-F^{II})$. (By subtraction (ii) and (iii)).

Now $y=l\sec\alpha+h-x\tan\alpha$,

$\therefore x=\frac{A(F^{I}-D)+L(l\sec\alpha+h)}{D+L\,(\tan\alpha)}$ By substitution of the value of y in (i)).

The pillars are easily removable from the beam, and fit into a special gauge bar for determining the angle α.

MEASURING THE RESISTANCE OF VIBRATING WIRES, CORDS, &c.

For this purpose, the balance is arranged to be somewhat to one side of the wind tunnel V, Fig. 10, and two arms W, W^1, project into the tunnel under wind screens, and carry the test piece Y. The arm W^1 is held rigidly by the beam C, but the arm W is pivoted on a vertical knife edge on the extension part U. The arms are connected at their opposite ends by a wire X provided with a nut X^1 adjusting the tension, and a spring X^{11} for measuring the same, and in the case of iron wires, it is intended to use electromagnetic devices to vibrate them at given frequencies.

Thanks are due to Mr. Patrick Y. Alexander for supplying the greater portion of the funds for erecting this apparatus. Thanks are also due to others, notably to Mr. E. A. Matzinger, for assistance in preparing the description and drawings, and in designing the balance and lamp rheostat, and to Prof. J. T. Morris for valuable assistance and the loan of electrical apparatus.

A. P. THURSTON.

THE AERODYNAMIC RESISTANCE OF BARS, STRUTS, AND WIRES—I

BY J. T. MORRIS, M.I.E.E. AND A. P. THURSTON, B.SC.

The apparatus used in these experiments consisted of a wind tunnel, a fan for producing a current of air in the tunnel, a balance for measuring the force on various rods mounted in the wind tunnel, and a Pitot tube and tilting gauge with which to determine the velocity of the air.

It will be unnecessary in this communication to give details of the arrangement of the wind tunnel and fan or of the balance used, as these have been fully described by one of the writers previously in this Journal ; but before proceeding to an account of the actual experiments, particulars of the tilting pressure gauge and Pitot tube and the exploration of the velocity of air in the tunnel must here be given.

THE TILTING PRESSURE GAUGE AND PITOT TUBE

The tilting pressure gauge was of a more simple form than that used by Dr. Stanton for the experiments described in his classical paper. It consisted of two vertical tubes of large diameter connected by a horizontal tube of small diameter partly filled with water. The vertical tubes were 39 mm. in diameter, which was found to give satisfactory results. The framework carrying the U shaped tube supported also a microscope, which was used to examine the meniscus of the water in one of the large tubes. There was therefore no motion between the microscope and the U shaped tube. The base of the gauge at the microscope end rested on two pivot points, whilst the other—the tilting end—was supported by the adjusting micrometer screw. The distance between the centres of the vertical tubes was 321 mm. and that between the pivot points and the adjusting screw 343 mm.

$$\therefore \frac{\text{lift of adjusting screw}}{\text{lift of vertical tube}} = \frac{343}{321}$$

$$\therefore \text{Pressure (in mm. of water)} = \frac{\text{lift of adjusting screw (mm.) } 321}{343} = \text{lift of nut} \times \cdot 936.$$

The formula given for the Pitot tube is $V = 1{\cdot}03\sqrt{2gH}$.

$$\text{Now H (ft. air)} = \frac{\text{Pres. (mm. water)}}{304{\cdot}8 \times {\cdot}00127}$$

·00127 being taken as the density of air $\therefore$ H (ft. air) = lift of adjusting screw × 2·417.

A curve was drawn giving the velocity in miles per hour in terms of the lift of the gauge in mm. and this curve was used in all cases to determine the velocity. It should

be noted that, since both the reading of the Pitot tube and the aerodynamic resistance of a specimen are momentum effects, i.e., formed by the product of density and velocity of the air, it follows that all the readings may be reduced to velocities at a constant density.

It was found possible to obtain very accurate readings of the meniscus of the surface of the water in the gauge in the following way. A sheet of white paper in front of an electric lamp was placed behind and slightly above the surface of the water and its position was adjusted until the bottom of the meniscus appeared as a straight dense line in the microscope. The horizontal line in the eyepiece of the microscope was given a slight inclination and was provided with two small dots on either side of the centre.

The level of the meniscus was adjusted until it cut the inclined line of the eyepiece between the two dots.

EXPLORATION OF TUNNEL

Velocity in Tunnel.—The velocity of the air in the tunnel could be varied from 0 to 31 miles per hour, but it was found convenient to run the fan at a speed which ordinarily gave a velocity between 21 and 22 miles per hour.

Bellmouth.—The first experiments were undertaken with a view to exploring the velocity of the air over a cross section of the tunnel.

Readings were taken with the bellmouth removed and in position. It was found that the resistance of the tunnel was decreased when the bellmouth was removed, but the current of air was steadier with the bellmouth in position.

Curtain.—In order to ease the passage of the air in passing through the lower chamber a curtain of oil baize partly stiffened with sheet steel was placed at the bottom of the tunnel as shown in Fig. 1 of the previous article. Readings of the velocity were taken with the curtain in position and removed. It was found that the curtain increased the velocity and decreased the fluctuations only by a small amount. As it was inconvenient to have it in the fan chamber it was decided not to use it in these experiments.

Longitudinal Distribution.—To ascertain the distribution of the air current at the position at which the specimens were to be mounted, two dynamic tubes were used. One was the tube of the Pitot set, and its position was fixed, the other being an identical tube which could be moved to any position in the same cross section of the tunnel. A number of tests were made with different arrangements of gauze, bellmouth, and curtain and the results are plotted in Fig. 1 for the longitudinal direction of the cross section of the tunnel.

The bellmouth is denoted by V
„ fine gauze „ „ .. .. —
„ coarse „ „ „ XI
„ nothing „ „ VI
„ curtain „ „ .. ..)

The position A is immediately below the bellmouth.
„ „ B is at the junction of the two portions of the top tunnel.
„ „ C is on the top of the short portion of the tunnel.
„ „ D is at the bottom of the short portion of the tunnel.

It will be noticed that No. VI. is the best as regards uniformity of distribution, but this arrangement is not convenient in use. No. XI. is nearly as good as regards distribution and is much more convenient in use. This latter arrangement was therefore adopted in the following experiments.

Neglecting those parts of the curve within 6 inches of the wall of the tunnel the results for test No. XI. are :—

Zero reading pressure gauge	=2·24mm.
Running „ „	=8·70mm.
Difference	6·46mm.
From the curve the variation	= ·26mm.
∴ the percentage variation	=4·03 %
∴ variation in velocity	=2·01 %

Test XII. gives practically the same percentage variation, whilst test XIII. gives a variation of 2·56 per cent. Taking the mean of the three tests the variation in velocity is between 2 per cent. and 2·25 per cent. The maximum divergence from the mean velocity is therefore about 1 per cent. Generally the specimen was shorter than the range considered above, and under these conditions the variation of velocity over the specimen would be less. The position of the specimen is shown at the top of Fig. 1.

Transverse Distribution.—Tests were made on the transverse distribution at the positions marked D, G and I, Fig. 1. The results are shown in Fig. 2. The amount of variation over the central portion is about the same as for the longitudinal distribution curves.

Position of the Specimen and Pitot Tube.—The position of the Pitot tube is indicated in Fig. 3, the dynamic tube being placed about $3\frac{1}{4}$ inches from the centre line of the tunnel. The centre line of the balance was about 3 inches from the side of the tube. A plan showing the position of the specimen, fixed end pieces and tunnel is given in Fig. 4.

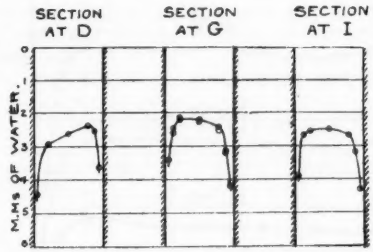


FIG 2

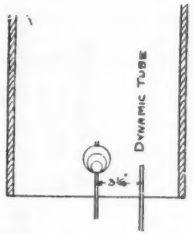


FIG 3

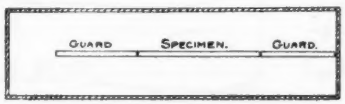


FIG 4

The velocity of the current was measured at the area of maximum restriction, i.e., on a level with the centre of the specimen. This position gives greater accuracy and allows of a larger specimen being used without the influence of the walls of the tunnel rendering the results inaccurate.

To illustrate this point the first three columns of the following table have been taken from Dr. Stanton's paper (vol. CLVI., Proc. Inst. C.E., p. 89). Column four has been worked out by applying the correction for restricted area.

	Velocity before reaching disk.	Velocity at a radius of 10 ins. in the plane of the disk A.	Velocity A corrected for restricted area.
	Feet per sec.	Feet per sec.	Feet per sec.
No disk	18·8	18·6	18·6
Disk 2 in. diam...	18·6	18·4	18·3
,, 3 in. ,, ..	18·8	19·1	18·8
,, 4 in. ,, ..	19·0	19·4	18·86
,, 5 in. ,, ..	19·0	19·6	18·76

FIG I

POSITION A B C D

1/ funnel
1/2 fine gauze
coarse "
nothing
0 curtain.

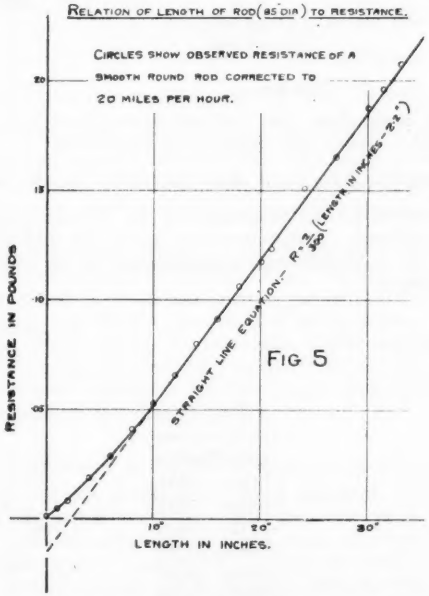
It will be seen that the last column gives substantially the same results as the first velocity column, when this correction is applied. If this correction be applied to the previous table in Dr. Stanton's paper (p. 88) it will be found that a disk of 3 inches diameter may be used in a 2 feet diameter tunnel without the wall causing an error in the result. It would appear to follow that in a one foot wide tunnel with long bars, a diameter of about $1\frac{1}{4}$ inches to $1\frac{1}{2}$ inches could safely be used, since in this case the air would be deflected in one direction only.

EXPERIMENTAL RESULTS ON RODS OF CIRCULAR SECTION WITH THEIR AXES AT RIGHT ANGLES TO THE DIRECTION OF THE AIR CURRENT

Turning now to the experimental aspect of the question. As has been shown above, with a wind tunnel of a given size there are certain dimensions which the test specimen must not exceed in order that the results obtained shall not be vitiated by too near an approach to the walls of the tunnel. On the other hand it is desirable that the specimens should be of a fair size in order that the magnitude of the force to be measured shall be reasonably large—hence the first experiments on the resistance of rods in this tunnel were made with the object of ascertaining the most suitable size of specimen.

In order to find the relation between the length of a rod and its wind resistance, a smooth round rod of wood ·85 inch in diameter and 34 inches in length was mounted in the tunnel with its axis at right angles to the direction of the air current; the resistance of this rod was then measured in an air current of from 20 to 23 miles per hour, after which equal lengths of an inch and a half to an inch were cut off from the two ends, the resistance being measured afresh at each step.

The results obtained are shown graphically in Fig. 5. It will be observed that the straight line which has been drawn, satisfactorily represents the observations from a length of 10 inches up to 30 inches. Above 30 inches there is reason to believe, as will be


RELATION OF LENGTH OF ROD (·85 DIA) TO RESISTANCE.
CIRCLES SHOW OBSERVED RESISTANCE OF A SMOOTH ROUND ROD CORRECTED TO 20 MILES PER HOUR.
STRAIGHT LINE EQUATION:- R = 3/300 (LENGTH IN INCHES - 2·2")
RESISTANCE IN POUNDS
20
15
10
·05
10"
20"
30"
LENGTH IN INCHES.
FIG 5

shown later, that the proximity of the ends of the wind tunnel begins to affect the results. Below 10 inches as would be expected the effect of the ends of the specimen becomes apparent, and the curve passing through the observations departs from the straight line. The direction of this departure indicates that for short rods the resistance decreases considerably faster than in direct proportion to the length.

Effect of ends of Specimens.—The principal cause of this lack of proportionality is due to the fact that the normal stream line motion of the air past a rod is interfered with in the neighbourhood of the ends, because some of the stream passes out laterally over the ends, and so has a horizontal component imparted to its velocity. The reaction of this component at each end of the specimen cancels out. The obvious result is that the parts near to the ends of the specimen offer less direct resistance to the motion of the air, than those parts which are near the centre.

When determining the resistance per foot run (or per inch run) of rods of various sections, it is desirable to eliminate, or, better still, to determine the magnitude of this "end effect." Hence certain experiments were carried out with this object in view.

Three different methods were examined :—

(*a*) Attaching plates to each end of the specimen.
(*b*) Subtracting force on a short specimen from that on a long specimen.
(*c*) Fixed end guards.

Method (*a*) *Attaching plates to each end of the specimen :—*

To the two ends of a wooden rod ·85 inch diameter and 12 inches in length, glass plates $8\frac{1}{4}$ by $6\frac{1}{2}$ by $\frac{7}{64}$ inch in thickness were attached at their centres.

This combination was then placed in position on the arm of the balance in the wind tunnel, and its resistance measured. The object of the end plates was to prevent the sideway motion of the air over the ends of the specimen.

The same experiment was then made with the 12 inch rod replaced by a 6 inch rod. The difference of the two resistances might have been expected to be that of a normal 6 inch length in the centre of a sufficiently long rod to eliminate this "end effect."

The results were as follows :—

	Mean of two experiments.
Resistance with glass end plates: 12 inch rod	=·1013
" " " 6 inch rod	=·0543
Difference	·0470

Now, other experiments show that the true figure of a 6 inch length is ·040, a discrepancy of 17 per cent. Hence this method was abandoned.

Method (*b*) *Subtracting force on a short specimen from that on a long one :—*

In this case the results for the resistances of the ·85 inch diameter rod for various lengths (Fig. 5) were utilized. Differences were taken, 21 inch from 33 inch, 18 inch from 30 inch and so on, each difference corresponding to 12 inch length. The results are given in the table below :—

Length in inches.		Resistance of a 12 inch length by difference.
33—21	·2075—·1232	·0843
30—18	·1875—·1060	·0815
27—15	·1650—*·0853	·0797
24—12	†·1450—·0654	·0796
22—10	†·1320—·0527	·0793
20—8	·1172—·0406	·0766
18—6	·1060—·0281	·0779
16—4	·0910—·0185	·0725
14—2	·0797—·0079	·0718
12—0	·0654—·0	·0654

*Calculated from 16 and 14. †Value from curve A.

These results are represented in the form of a curve in Fig. 7. An examination of these results leads us to the following conclusions.

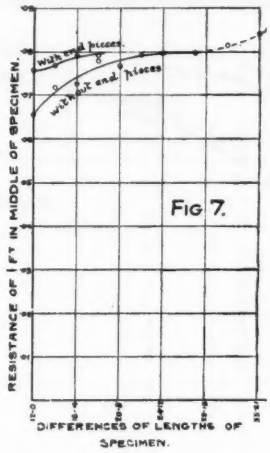


FIG 7.

For a rod ·85 inch in diameter :—

(1) That the end effect is a gradually increasing quantity up to some ten inches, i.e., until the specimen is some twelve diameters in length.

(2) That is it substantially correct to subtract the resistance of a rod ·85 inch diameter not less than 10 inches in length $\left(\frac{l}{d} > 12\right)$, from the resistance of a rod of the same diameter, but 12 inches longer in order to obtain the true resistance per foot run.

(3) That for the particular wind tunnel used in these experiments it is not advisable to use specimens which are more than 30 inches in length, as the proximity of the walls of the tunnel in the direction of the axis of the specimen begins to alter the normal flow of the air over the ends.

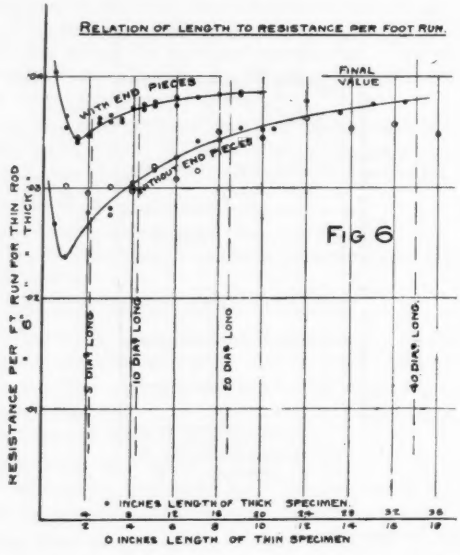
This limitation is due to at least two causes, firstly that the velocity of the air current near to the walls of the tunnel is considerably below the average velocity, and secondly, that the flow of air over the ends of the specimen is, on account of the proximity of the walls, altered more nearly to the flow at the centre of the specimen. This effect is probably the more important of the two for the maximum length used in these experiments, i.e., 33 inches, one end of the rod being about 5 inches from the wall of the tunnel. This latter effect would *increase* the difference for the 12 inch length, and thus explain the rising portion (shown dotted) of the curve Fig. 7.

Method (*c*), *Elimination of end effects by means of end guards* :—

It was thought that if three pieces of the same specimen were arranged carefully in exact alignment, the two end pieces being fixed, the force on the middle piece would correctly represent the true resistance per foot run, thus eliminating the "end effect" from the centre specimen, as the "end effect" would be wholly confined to the two fixed end pieces. This would be true on the assumption that the ratio of the length of the end pieces to their diameter is sufficiently great, and provided also that the crevices between the fixed and moving specimen are sufficiently small not to alter appreciably the stream line flow from that of a perfectly continuous specimen.

The results of experiments to test this method are shown in Figs. 6, 7 and 8.

From Fig. 6 it will be seen that the calculated resistance per foot run for a specimen 7 diameters long is deficient by 28 per cent. of its true value, if tested alone; whilst if



fixed end pieces are used, the value obtained is deficient by only 9 per cent. These experiments show that if suitably arranged end pieces be used, one can obtain equally accurate results with shorter specimens.

If in addition to using the end pieces, the method of taking differences described above be employed, instead of the shorter specimen requiring to be some 12 diameters in length, 6 diameters is sufficient. Fig. 7 represents these results.

In order to investigate this matter more fully, experiments were made to determine how accurately it was necessary to set the parallel gaps to secure reliable results. The table given below shows that in order to obtain the true resistance per foot run from a 6 inch specimen ·85 inch diameter, it is necessary to reduce the gap to about $\frac{1}{64}$ of an inch to secure one per cent. accuracy without using the method of differences.

Round rod about ·85 inch diameter and 6 inches in length (about 7·1 diameters in length):—

Gap.		Percentage deficiency on 6 in. length
$\frac{1}{128}$	inch	4 per cent.
$\frac{1}{64}$	,,	7 ,,
$\frac{1}{4}$	,,	12 ,,
$\frac{1}{2}$	,,	18 ,,
1	,,	$23\frac{1}{2}$,,
$1\frac{1}{2}$	,,	25 ,,
7	,, and upwards	28 ,,

These results are given in the form of a curve in Fig. 8.

RESULTS AND COMPARISON WITH THE WORK OF PREVIOUS EXPERIMENTERS

The results obtained for the ·85 circular rod can be expressed in the following form.

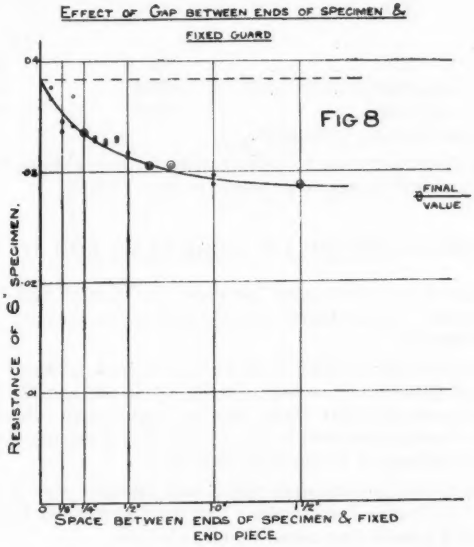
From one foot and upwards (without end pieces):—

Pressure = ·0133 (length in inches—2·2) .. .. (1)

From eight inches and upwards (with end pieces) :—

(2) Pressure = ·0133 (length in inches—0·6).

These results are in lbs. per square inch at 20 miles per hour.


EFFECT OF GAP BETWEEN ENDS OF SPECIMEN & FIXED GUARD
FIG 8
FINAL VALUE
RESISTANCE OF 6" SPECIMEN.
SPACE BETWEEN ENDS OF SPECIMEN & FIXED END PIECE

In order to compare them with the work of other investigators, the pressure is converted into lbs. per square foot and then the equation becomes for this circular rod ·85 inch diameter

$$P = \cdot 00282\ (ld - 2 \cdot 59 d^2) V^2 \qquad (3)$$

Where V = velocity in miles per hour.
,, d = diameter of rod in feet.
,, l = length of rod in feet.
,, P = resistance in pounds.
The air having a density ·00127.

If the standard conditions of 14·7 lbs. per square inch and temperature 60° Fah. are assumed, the density then becomes ·00122, and the above formula stands :—

$$P = \cdot 0027\ (ld - 2 \cdot 59\ d^2) V^2. \qquad (4)$$

Dr. Stanton gives for circular and square plates up to about 2 inches in diameter

$$P = \cdot 0027\ A\ V^2 \qquad (5)$$

It is a rather strange coincidence that the constant is the same in the two equations, but this is due to known factors operating in opposite directions.

The consideration of the constants 2·2 and 0·6 in equations (1) and (2) suggests the following as another possible method of obtaining the true resistance per foot run for a circular rod ·85 inch diameter of more than a foot in length. Measure the resistance of the rod and take as its effective length its actual length minus 2·2 inches. This will

give a true result. Or if fixed end pieces are used arranged with a working clearance, deduct 0·6 inch instead of 2·2.

Further, it was thought probable that the "end effect" would be similar for circular bars of differing diameters, but having the same ratio of length to diameter, so the equation was put in the form shown in (3). This has been tested by the experimental results obtained on two circular rods ·85 and ·427 inch in diameter respectively (shown in Fig. 6 by dots for the larger rod, and by circles for the smaller), and the results are given below. :—

Length	12	12
Diameter	·85	·427
Resistance observed	·0654	·0362
Resistance calculated	·0653	·0365

which shows a very satisfactory agreement.

Unfortunately, there is reason to believe that for other diameters this equation is not strictly accurate, as will be apparent from the next section.

RELATION OF THE DIAMETER OF A CIRCULAR ROD TO ITS RESISTANCE

Having determined the connection between the length and the resistance of a specimen, the next point to investigate was the connection between the diameter of the specimen and its resistance.

Brass tubes and circular wooden rods having smooth surfaces were experimented with of the following diameters in inches :—2, $1\frac{3}{4}$, $1\frac{1}{2}$, $1\frac{1}{4}$, ·974, ·832, ·532, ·412, and ·308. It was found experimentally that there was no appreciable difference between the resistance of smooth wooden rods and brass tubes of the same size, showing that the skin friction is not greatly influenced by the kind of surface.

The method employed to eliminate the "end effects" was a combination of the "end guard" and "difference" methods. The lengths selected being 18 and 6 inches respectively. The end guards were about a foot in length.

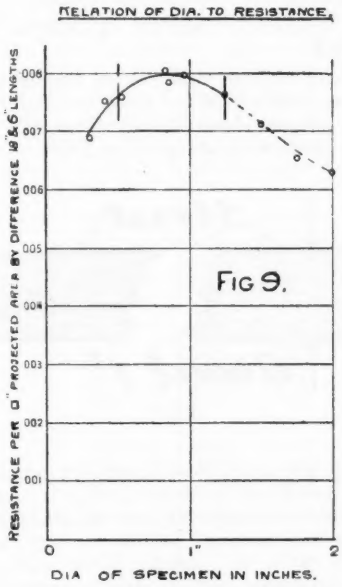
The table appended gives the collected results. The last line shows the results obtained for the 0·85 inch wooden rod which was used to show the relation of resistance to length.

Diam. of rod in inches.	Resistance (reduced to 20 m.p.hr.) in pounds.		Difference 18 in.—6 in.	Resistance per square in. of projected area.
	18 in. length.	6 in. length.		
2·00	·2230	·0722	·1508	·00629
1·75	·2033	·0660	·1373	·00654
1·50	·1887	·0606	·1281	·00712
1·25	·1671	·0525	·1146	·00764
0·974	·1345	·0414	·0931	·00797
0·832	·1190	·0387	·0803	·00806
0·532	·0721	·0237	·0484	·00759
0·412	·0547	·0176	·0371	·00751
0·308	·0394	·0140	·0254	·00687
0·85			·0800	·00785

In the last column is given the resistance per square inch of projected area.

It might have been expected that this quantity would have been constant; but it will be observed that it rises from ·00687 for the smallest diameter to about ·0080 for a rod of about $\frac{7}{8}$ inch in diameter, beyond which, further increase in the diameter decreases the factor.

Now it may be that this decrease, particularly when the rod exceeds $1\frac{1}{4}$ inches in diameter, is due to the limitations of the tunnel. That this might be expected was shown earlier in the paper by inference from Dr. Stanton's work.



As far as this investigation goes it appears certain that the resistance per square inch of projected area increases as the diameter is increased up to about one inch. For diameters greater than this it is not possible for the authors to speak with certainty as yet. As a possible explanation of the increase of this factor up to one inch it might be suggested that owing to the greater depth of the specimens in the direction of the air current an increase in this factor would thereby be caused.

Since the average thickness of the struts used in aeroplanes ranges from half an inch to an inch and a half, the possible limitations of the tunnel would not seriously affect the results.

The authors wish here to acknowledge their indebtedness to Mr. F. L. Cunningham for much painstaking work in connection with this communication. They desire also to record their grateful thanks to the Laboratory Committee of the Aëronautical Society of Great Britain at whose instigation the research is being made, and for financial assistance rendered in connection with it.

The authors would also express their thanks to the Governors of the East London College for permission to carry out the work in the Aerodynamical Laboratory at the College.

TESTS OF WOOD STRUTS

Made at East London College (University of London) for the Laboratory Committee of the Aëronautical Society of Great Britain

BY PROFESSOR D. A. LOW

THE object of the tests here described was to determine the strengths of comparatively slender wood struts, and to find, if possible, the most suitable kind of wood to use for struts in aeroplanes, having regard to strength and lightness.

The samples of wood were kindly supplied by Messrs. Wm. Mallinson and Co., Hackney Road, London, N.E.

Each strut tested was of uniform cross section throughout its length, the section being rectangular, about two inches wide and about one inch thick. Seven of the struts were about 32 inches long, one was about 30 inches long, and the remaining fifteen were 24 inches long. The exact dimensions are given in Table I.

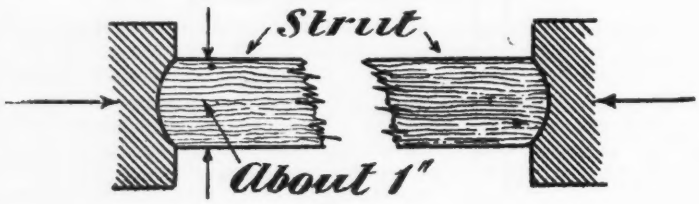


Fig. 1.

The struts were tested in a 50 ton Wicksteed testing machine. The ends were rounded and fitted into grooves in iron blocks as shown in Fig. 1. Each strut was placed truly vertical and the load, applied vertically, was put on gradually until the strut buckled or crippled. The crippling load was quite definite in every case and was the maximum load which the strut would carry, any pushing of the ends of the strut nearer to one another by working the pump simply bent the strut more and more without any increase in the load. In fact after being crippled the strut could be broken with a load less than the crippling load.

It was assumed that the Euler formula for struts with hinged ends was the most suitable for these struts. The formula is $P=\frac{\pi^2EI}{l^2}$ where P is the crippling load, E the modulus of elasticity of the material, I the least moment of inertia of the cross section, and l the length of the strut.

The crippling loads P are given in Table I. The values of E were calculated by the Euler formula already given. But the values of E calculated in this way were, in almost every case, high, and were in fact, on the average, about double the values which were obtained by direct experiment on the elastic deflection of the struts tested as beams.

It would seem, therefore, that the resistance to buckling due to the friction at the ends of the strut had the effect of fixing the ends to a certain extent, so that using the actual value of E from the elastic deflection experiments the formula would be $P=\frac{2\pi^2EI}{l^2}$ which is the Euler formula for a strut fixed at one end and free at the other, but guided in the direction of the load. The formula $P=\frac{2\pi^2EI}{l^2}$ will therefore be used as applying to these tests.

TABLE 1.

N=number of specimen. l=length of strut in inches.
b=width of strut in inches d=thickness of strut in inches.
I=least moment of inertia of section in inch units=$\frac{1}{12}bd^3$.
P=crippling load in tons.
E=modulus of elasticity in tons per square inch, calculated from the Euler formula $P=\frac{2\pi^2 EI}{l^2}$

N.	Material.**	l	b	d	I	P	E
1	American Ash	31·9	2·024	1·073	·209	2·44	604
2	American Ash	24·0	2·038	0·843	·102	2·14	612
3	Basswood	29·87	1·862	0·866	·101	1·88	843
4	Hickory	24·0	1·975	0·938	·136	3·63	780
5	Hickory	24·0	1·956	0·980	·154	4·29	818
6	Hickory	24·0	1·966	0·997	·163	5·19	918
7	Honduras mahogany ..	32·0	2·025	1·042	·191	2·78	756
8	Honduras mahogany ..	24·0	2·062	1·002	·173	3·85	650
9	Honduras mahogany ..	24·0	2·073	0·971	·159	3·69	682
10	Parang*	32·0	2·060	0·919	·133	3·19	1,242
11	Parang*	24·0	2·192	0·780	·087	2·48	832
12	Parang*	24·0	2·180	0·765	·081	2·80	1,009
13	Spruce	31·9	1·950	1·104	·219	2·95	696
14	Spruce	32·0	1·992	0·955	·145	2·62	904
15	Spruce	32·0	1·897	0·990	·154	1·85	1,073
16	Spruce	24·0	1·965	1·208	·289	4·81	486
17	Spruce	24·0	1·957	1·206	·286	4·83	493
18	Spruce	24·0	1·967	0·925	·130	2·06	463
19	Spruce	24·0	1·969	0·972	·151	2·24	433
20	American Walnut ..	24·0	1·861	1·060	·185	4·61	727
21	American Walnut ..	24·0	1·818	0·928	·121	3·21	775
22	Walnut	24·0	1·882	1·026	·169	3·96	684
23	Whitewood†	31·9	1·866	0·842	·093	1·66	922

*Parang is a hybrid wood from Eastern Asia. In appearance it resembles mahogany.
†American Poplar.
**There were three kinds of Spruce amongst the samples Nos. 13 to 19. No. 13 is Best Quebec Spruce, but this is ruled out for aeroplanes as it cannot now be obtained perfect in sufficient lengths. Nos. 14, 16, and 17 are the Silver Spruce. This wood cannot be obtained perfect in very long lengths, but it is fairly constant in quality. Nos. 15, 18, and 19 come from different parts of America. This wood varies considerably, and only a few planks out of a big parcel are perfect. Planks often have a large number of small knots.
We are not sure that the Parang was perfectly seasoned.
Basswood, at present, is only obtained in thicknesses not exceeding 1 inch. Basswood is often confused with American Whitewood (No. 23).—W. M. & Co.

The following notes refer to the condition of the various specimens when the crippling load was reached.

Specimens 1, 2, 4, 5, 11, 12, 13, 15, 18 and 23 were bent but not fractured.

In 3 there were signs of fracture on the compression side. In 7, 10 and 14, fracture started on the compression side. In 16, 17 and 19 there was decided fracture on the

compression side. In 6 fracture took place on the tension side after the load was continued. In 20 and 21 fracture took place on the tension side. In 8 and 9 fracture took place in tension and in compression. In 22, fracture started in tension and in compression.

Crushing tests were made on pieces about 2 inches long cut from the ends of certain of the specimens after they had been tested for the crippling load. The pieces so tested were in no way injured by the previous test for the crippling load. The crushing load was applied in the direction of the grain of the wood. The results are given in Table II. The numbers of the specimens given in column 1 of Table II. are the same as the numbers of the specimens in Table I. from which they were cut. The crushing load in each case was quite definite.

TABLE II.

f=crushing stress in tons per square inch.

N	Material.	f	N	Material.	f
1	Ash	2·92	13	Spruce	2·41
2	Ash (American)	1·75	14	Spruce	2·46
3	Basswood	2·98	15	Spruce	2·24
4	Hickory	3·33	16	Spruce	2·62
7	Honduras mahogany ..	2·53	18	Spruce	2·08
8	Honduras mahogany ..	2·41	20	Walnut (American) ..	4·15
10	Parang	4·12	23	Whitewood	2·65
11	Parang	2·97			

Specimens 8, 13, 14, 16 and 18 gave way by crushing. Specimens 1, 2, 3, 4, 7, 10, 11, 15, 20, and 23 gave way by shearing. Figs. 2—6 illustrate fracture by shearing in crushing tests.

Fig. 2.

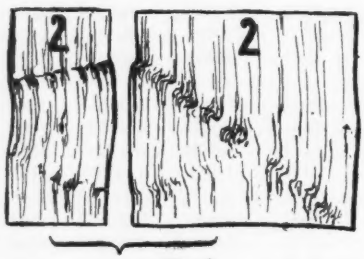


Fig. 3.

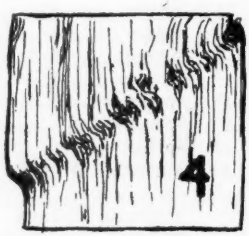


Fig. 4.

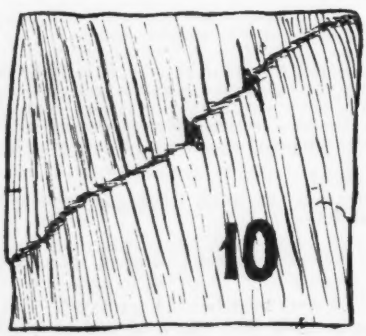


Fig. 5

Fig. 6.

The various struts were carefully weighed and their volumes computed, and from these the density or weight w in lbs. per cubic inch was calculated. The results are given in Table III.

TABLE III.

N.	Material.	w.	N.	Material.	w.
1	Ash	·020	13	Spruce	·016
2	American Ash	·020	14	Spruce	·015
3	Basswood	·018	15	Spruce	·014
4	Hickory	·028	16	Spruce	·018
5	Hickory	·026	17	Spruce	·017
6	Hickory	·028	18	Spruce	·015
7	Honduras mahogany ..	·018	19	Spruce	·015
8	Honduras mahogany ..	·017	20	American Walnut ..	·022
9	Honduras mahogany ..	·017	21	American Walnut ..	·023
10	Parang	·024	22	American Walnut ..	·020
11	Parang	·022	23	Whitewood	·018
12	Parang	·022			

In order to compare the suitability of the various kinds of wood tested for struts for aeroplanes, the results of the tests have been used to calculate the dimensions for struts of each kind of wood 30 inches long to carry a crippling load of 3 tons. The results are given in Table IV. The struts are placed in the order of their weights W in lbs. The cross sections of the struts have been made symmetrical, of breadth b and thickness d, b being equal to $2d$ in each case. The last column gives the number of test struts upon which the results are based, the values of E and w being the means from that number of specimens.

TABLE IV.

Material.	b	d	E	w	W	Number of tests.
Whitewood	1·94	0·97	922	·018	1·02	1
Basswood	1·98	0·99	843	·018	1·06	1
Spruce	2·12	1·06	650	·016	1·08	7
Honduras mahogany	2·08	1·04	696	·017	1·10	3
Parang	1·90	0·95	1,028	·023	1·25	3
Walnut	2·06	1·03	729	·021	1·34	3
Ash	2·16	1·08	608	·020	1·40	2
Hickory	1·98	0·99	839	·027	1·59	3

The foregoing tests seem to indicate that Whitewood (American Poplar), Basswood, Spruce and Mahogany are the most suitable woods for the struts of aeroplanes. Hickory is a very tough wood and may be bent to a considerable extent without fracturing, but it will be noted that it is the heaviest of all the woods tested.

It would, of course, be more satisfactory if a larger number of tests could be made with specimens of the kinds of wood which on account of their strength and lightness are obviously most suitable.

Table V. gives the Euler formula in its simplified form for use in designing struts of the more suitable of the materials tested, the constants being derived from the results of the tests made. It must be understood, however, that the formulae here given are for struts loaded as in the tests here described. As has been indicated the conditions of the tests seem to be equivalent to that of a strut fixed at one end and free at the other, but guided in the direction of the load. The Euler formula for this case being $P=\frac{2\pi^2EI}{l^2}$. In an aeroplane the condition of a strut is probably that of one fixed at one end and free at the other, but not guided in the direction of the load. For this case the Euler formula is $P=\frac{\pi^2EI}{4l^2}$. Hence, for aeroplane struts the expressions given for P in Table V. should be divided by 8.

If n is the factor of safety then the safe working load will be $\frac{P}{n}$

TABLE V.

Material.	Formula.	Number of tests.
Whitewood	$P=18{,}299\frac{I}{l^2}$	1
Basswood	$P=16{,}864\frac{I}{l^2}$	1
Spruce	$P=12{,}832\frac{I}{l^2}$	7
Honduras mahogany	$P=13{,}848\frac{I}{l^2}$	3
Parang	$P=20{,}350\frac{I}{l^2}$	3
Walnut	$P=14{,}393\frac{I}{l^2}$	3
Ash	$P=11{,}907\frac{I}{l^2}$	2
Hickory	$P=16{,}864\frac{I}{l^2}$	3

The cross section of an aeroplane strut will, of course, not generally be a rectangle, but whatever its form its least moment of inertia I must be computed and substituted in the formula for determining the crippling load.

In conclusion the author would express his indebtedness to Mr. W. G. Mann and Mr. J. Brimelow for their most valuable help in making the foregoing tests and the numerous calculations connected with them.

A NEW THEORY OF THE BIRD'S WING AND ITS APPLICATION IN AVIATION

BY H. B. MOLESWORTH, M.I.C.E.

IT has generally been accepted that the feathers in the bird's wing are the outcome of nature's effort to provide a plane surface and that the resulting wing acts as a simple plane when in use either for soaring or propelling.

As egards soaring the explanations even under this supposition appear adequate, but when the wing is used as a propeller or for lifting the bird, the usual explanations have a'ways appeared to the author as extremely unconvincing.

On examining the wing of a bird it will be noticed that the feathers are so arranged that the leading feather is the lowest.

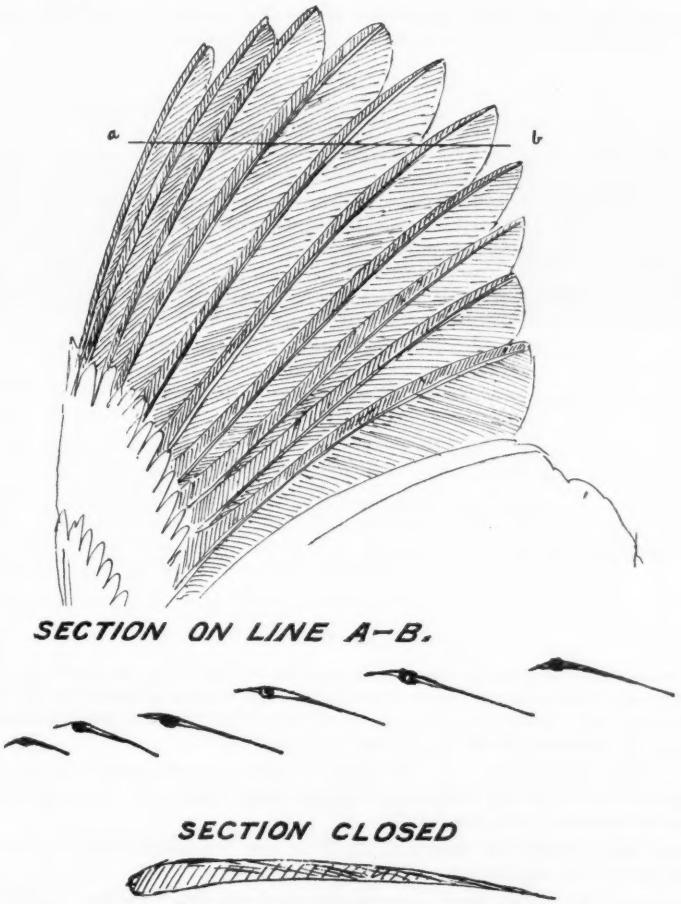


FIG. 1.—PARTRIDGE WING. TOP VIEW.

When the pressure of the air is on the under side of the wing, the feathers, especially near the end of the wing, (where the main part of the work is done when flapping), separate; and the air can pass freely between the feathers. The result of this separation is that the area is enormously increased. For instance in the wing of a partridge the width across the feathers when in thei closed position is 3½ inches, but when the feathers separate the sum of the width of the feathers is slightly over 10 inches. This opening is mostly automatic and is due principally to the flexibility of the feathers and the way in which they are arranged.

When the pressure on the underside of the wing is reduced (or as may conceivably be the case on the upward stroke of the wing) reversed, the feathers close on one another and the area is reduced.

If this theory be accepted we get at once a reasonable explanation of the effectiveness of the bird's wing—not only as a supporting plane but also as a propelling and lifting apparatus.

The bird's wing is apparently used, sometimes with the feathers closed together to form a single plane of reduced area, and sometimes with the feathers separated to form a series of planes with a greatly increased area.

In flapping the wing feathers tend to separate on the down stroke and close on the up stroke, and the changes in the arrangement of the feathers, although mainly automatic, are to a great extent under the control of the bird.

For rapid flight when speed has been attained the feathers are probably closed, but for slower flight and soaring, the feathers are probably separated.

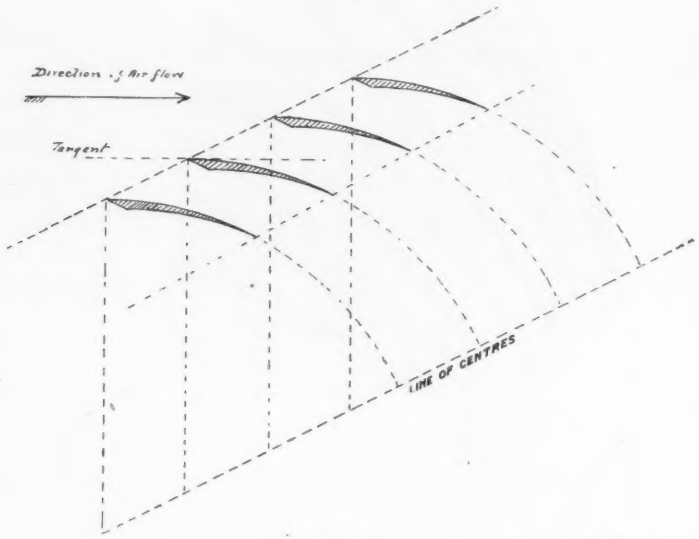


FIG. 2

The cross section of a bird's wing will be seen to be convex on the upper side, concave on the lower side, with a thickening near the front edge, and each feather in the wing has a cross section very similar, *i.e.*, it is convex on the upper side, concave below, and with a thickening (in this case the rib or quill) near the front edge.

Most of the soaring birds, *e.g.*, the eagle, vulture, kite, etc., soar with the feathers widely separated near the end of the wing—and it is only reasonable to assume that there is some definite purpose in such separation.

Having stated briefly the theory as above, it now remains to be seen whether any use can be made of its suggestions in the design of Aeroplanes.

In designing the planes for an aeroplane embodying this "feather" principle, and taking, for the sake of simplifying the drawing, circular curves for the cross section of the planes, several curious results are obtained which seem to fit in with the theory and to a certain extent confirm it:—(1st) If a series of arcs of circles representing the cross sections of planes be struck with equal radii tangential to parallel lines and with their tangent points arranged in a sloping line, the distance between the successive circles

will increase from a minimum at the tangent point to a maximum at a line drawn through the centres of the circles. The result of this is that the efflux area increases towards the back of the planes.

(2) If ribs be put on the concave side of each plane near the tangent point, or leading edge, the distance between the surfaces of the planes will first diminish and then enlarge, forming a passage for the air approximating to the "Vena contracta" which is the best form for orifice for passing fluids or gases.

FIG. 3.—THE MOLESWORTH-HUGHES EXPERIMENTAL MULTIPLANE

(3) The efflux from beneath each plane is deflected downwards quite clear of the plane below it.

(4) The vortices or whirls caused in air by the passage of single planes through it are considerably diminished by the air being confined in definite stream flow channels.

It will be seen that all these points are found in the bird's wing.

It is possible that the problem which now is exercising so many able minds, *i.e.*, the alteration of the area of the planes of an aeroplane to suit varying conditions of speed and weight, may find herein its ultimate solution.

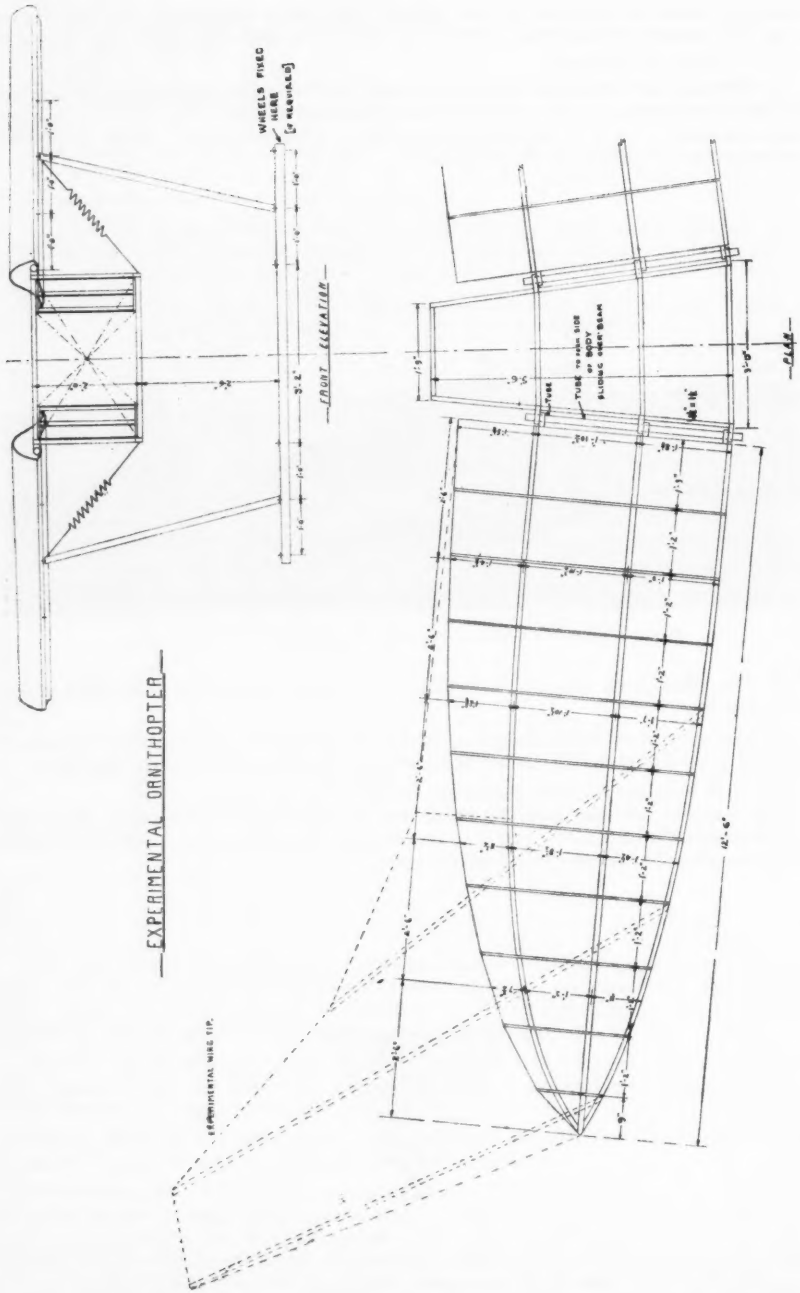

EXPERIMENTAL ORNITHOPTER
WHEELS FIXED HERE (IF REQUIRED)
FRONT ELEVATION
SIDE ELEVATION
EXPERIMENTAL WING TIP

FIG. 1

REPORT OF THE WINGS COMMITTEE

F. HANDLEY PAGE (*Chairman*) THE HON. HENRY S. LITTLETON
T. B. BAKER P. NARRAWAY
R. M. BALSTON G. P. D. SAUL
J. LEDOUTHET A. CHATTERTON SIM

THE Committee considered several methods of carrying out the wing experiments, and came to the following conclusions :—

(1) That to obtain accurate quantitative results the experiments should be made with models suitably mounted and driven in a " wind tunnel " on a " whirling table," or by other methods of artificially imitating the effects obtained in free flight. Experiments in free flight could only give accurate and useful quantitative results if carried out with full-sized machines—a course of experiment precluded by its excessive cost.

(2) Before these quantitative model experiments were carried out a series of qualitative tests would have to be made to determine by comparison the relative efficiency of different types of wings and the different propulsive forces obtained with various wing constructions.

(3) To carry out these quantitative experiments in a wind tunnel would entail a greater cost than the funds at the disposal of the Committee could meet. The models would require to be very accurately made, and would therefore be costly.

A pair of wings having been offered on loan to the Committee, it was decided to carry out a series of quantitative experiments with these in the open. Various sets of wing tips could be fitted and the relative value of each tested.

A drawing of the wings is shown in Fig. 1, giving the general details and dimensions.

The general arrangement of the wing-flapping motion is that originated by Major Moore, and upon which a Committee of the Aëronautical Society carried out a series of experiments. The method will be found fully described in the report of that Committee (AËRONAUTICAL JOURNAL, January, 1909).

Plans were discussed for a chassis suitable for the flapping wing motion, and the arrangement outlined in the drawing was put in hand. Briefly this is as follows :—

The central chassis or frame is mounted on four pneumatic-tyred wheels. On the frame there are four vertical struts which swivel at either end, allowing the horizontal movement of the wings that occurs when the central body is moved up or down. The springs on either side of the body absorb the power given out on the upstroke by the falling of the body, and return it on the down stroke in accordance with the general idea of Major Moore's arrangement.

DESCRIPTION OF EXPERIMENTAL ORNITHOPTER.

Body. The body is 6 ft. long by 2 ft. 6 in. square. It consists of four wooden spars connected with suitable struts and bracings, having on either side tubes carried on brackets. In the centre is fixed the seat for the operator. The lower ends on each side of the body are provided with clips for attachment by means of springs to the wings.

Chassis. The chassis consists of two front wheels and one back wheel, the back wheel being mounted on a spring axle. From the chassis there is four upright vertical struts pivoted at the top and bottom, the top part being connected to the wings. On the chassis is fitted a foot rest.

Wings. The wings fit into the body by means of a small attachment fitted to the end of each wing.

NOTES

The Aero and Motor Boat Exhibition, Olympia (March 24—April 1). The general impression of the Show was decidedly encouraging. British-built machines preponderated, and the workmanship and finish furnished a striking advance in comparison with last year's exhibition. There was a total of 27 machines on view, including 15 monoplanes, 9 biplanes, a tandem aeroplane and an ornithopter; of these, 7 were French (4 Blériot's, a Bréguet, a Nieuport, and a Maurice Farman), and one American.

Members of the Aëronautical Society showing machines were Mr. S. F. Cody with his immense biplane, the British and Colonial Aeroplane Company with two biplanes and a monoplane, the Blair-Athol Syndicate with the new Dunne monoplane, Messrs. Handley Page with a monoplane, and Mr. Alec. Ogilvie with a "Baby" Wright.

While, with the exception of the Dunne monoplane, there was very little that was novel, there was much in details that was extremely interesting: such as the hollow built-up wood body of the Handley Page monoplane, the general construction of the Sanders biplane, the finish of the "Baby" Wright (the tail of which, by the way, appeared exceedingly insecure), and the wiring of the Aeronautical Syndicates' "Valkyrie" monoplanes. Noteworthy, too, were the enclosed body of the Nieuport monoplane, here seen for the first time in this country, the novel flexible wing-structure of the Bréguet biplane and its device for folding back the wings for transport, and the curious camber on the smaller of the two Bristol biplanes.

Aerial engines were well represented, and included several new types of interesting design, among them a considerable number of British manufacture. In propeller design, on the other hand, there were no innovations to record, save perhaps in regard to more perfect workmanship and finish.

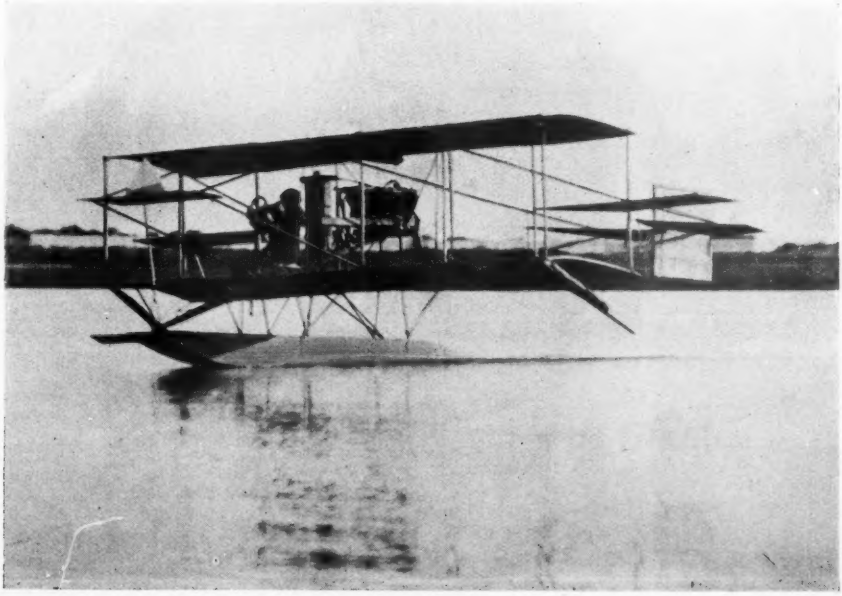
The Curtiss Hydro-Aeroplane The photograph reproduced facing this page illustrates Mr. Glen Curtiss in his latest type of hydro-aeroplane travelling at 40 m.p.h. on San Diego Bay (Cal.). The original experimental type was fitted with two floats, a water-shield and a large pontoon, but in the present type a single pontoon is all that is used. This pontoon, which is covered with canvas, is 12 feet long, 2 feet wide, 1 foot deep and 50 lb. in weight. The plan shape is rectangular, while the view in section shows that at a distance of 3 feet from the front edge the bottom curves upward, forming a sharp edge on a level with the top of the pontoon; similarly the top curves down 3 feet from the rear edge, to meet the bottom. The pontoon is situated slightly in front of the centre of gravity of the machine, giving it a slight tilt that assists it to rise. A skid, 4 feet long and 3 inches wide, carrying an inflated rubber tube, is placed under each end of the lower plane to prevent the tips from touching the water when turning. The first trial was a complete success, the machine rising easily from the water and gliding on the completion of the flight to the water, on which it alighted without a splash. The aeroplane used was of the usual type of Curtiss biplane. The latest development has been the addition of wheels in front and behind the pontoon, so that, given a firm shelving beach, the machine can go from water on to land, and *vice versa*, with the same ease with which it rises from either of these denser elements into the air.

A New Method of Springing Chassis The general method of mounting wheels of the "Farman" type, is by supporting the weight of the aeroplane on rubber bands which pass over the axle, and round rollers in brackets on the skid. The grave objection to this method is the breakage of the rubbers, owing mainly to small initial cuts, caused by friction on the rollers, on the axle and round the sharp bends, and to unequal strains set up by friction. In order to provide a more durable spring it is most desirable that the extension and contraction should be in a straight line.

The methods shown in the sketches on page 92 (which have been patented by Mr. H. B. Molesworth) permit of the use of a "shock absorber" of rubber, or a spiral spring, either of which are perfectly durable under varying shocks and loads. The cost of this method is less than that of the rubber bands which it is intended to replace, and as regards durability there is no comparison. A further advantage of this method is that by the use of an ordinary tightening screw, the tension on the spring can be varied as required.

As the "Farman" type of wheels is very generally used, there is a wide field for any improvement which will increase its efficiency.

THE SOCIETY'S STAND AT AËRO SHOW, OLYMPIA



THE CURTISS HYDRO-AEROPLANE

Military Aviation The following telegram is reprinted as an historical document of some little value, and as evidence of a point in favour of this means of communication which seems to have been overlooked hitherto. We have called attention to it by italics.

San Diego, California,
February 7, 1911.

GENERAL ALLEN,
Chief Signal Officer, U.S.A.,
Washington, D.C.

I have the honor to inform you that Harry S. Harkness to-day flew from Aviation Camp on North Island opposite Fort Rosecrans, to the encampment of the U.S. Troops on Mexican Border near Tialfuans, carrying message from Major McManus, Commanding Fort Rosecrans, to his subordinate Lieut. Ruhlin. The flight was eminently successful. Entire distance covered, 45 miles. Was in the air 56 minutes. Encampment of regulars 21 miles from Fort Rosecrans. Message was in hands of officer 25 minutes after delivery to Harkness. *Roads between points practically impassible through recent rains.*

D. C. COLLIER,
President, Aero. Club,
San Diego.

4.37 p.m.

A New Aeroplane Compass A liquid compass has recently been invented for aeroplanes by Mr. E. H. Clift, which possesses the advantage of an absolutely steady card when the machine rolls and pitches, and is not affected by vibrations. The card and needles are so made and mounted as to free them from the dragging effects of the liquor, and after any deflection or movement they come to rest with one oscillation.

A lever can be worked from the bottom to lift and clamp the card off the centre when not in use, and an entirely new feature of the compass is the course pointer on the top of the card. When the card is lifted off its centre a small arm can be worked from the top glass of the compass to turn this course pointer to any point on the card, and there it remains until a new course is set. In this way the pointer clearly indicates which point is to be steered by, and does away with any danger of forgetfulness or confusion of points. A small segment of transparent material with a white mark in the centre and red and blue arcs each side moves with this pointer, and at night time is illuminated from below by a small electric lamp. When on the correct course the white light will show; if right or left the red or green gives a warning at once to which side the vessel is off her course.

The compass is suspended on gymbals and slung on four special springs which give absolute steadiness and freedom from shocks and vibration.

The weight of aeroplane compass complete with suspension is about 4 lb.

Mr. G. Hamel used one on his flight from Hendon to Brighton and back, and reported that it worked excellently.

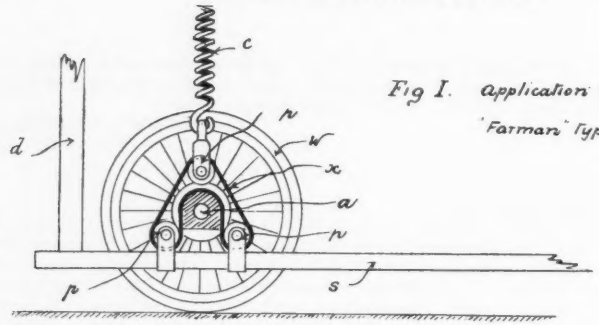
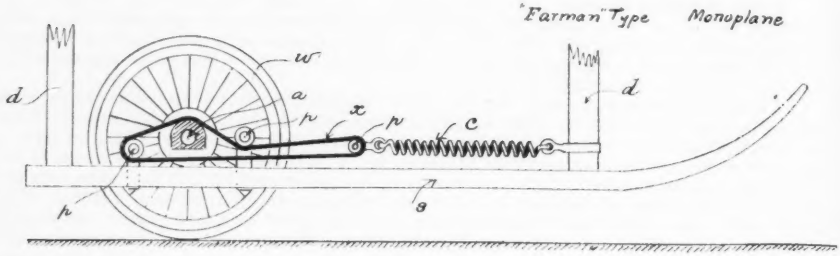


Fig 1. Application to existing wheels "Farman" Type Biplane

Fig 2. Application to existing wheels "Farman" Type Monoplane



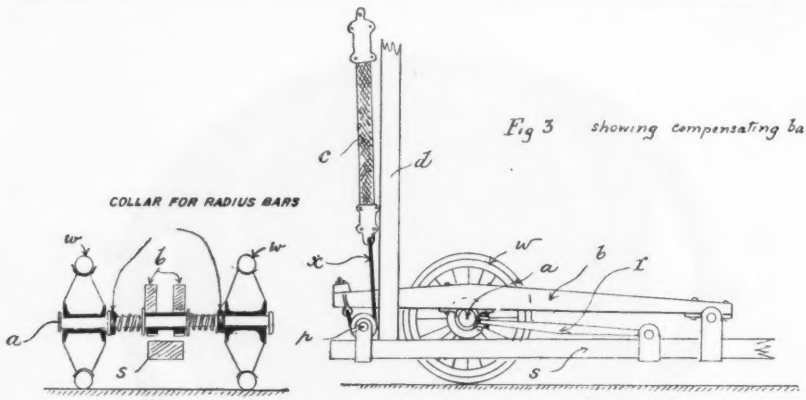


Fig 3 showing compensating bars

a - axle of wheels
b - compensating bars
c - shock absorber or spiral spring
d - struts to fuselage of aeroplane
s - skids
r - radius bars
w - wheels
x - wire rope, band or chain.
p - pulleys or rollers

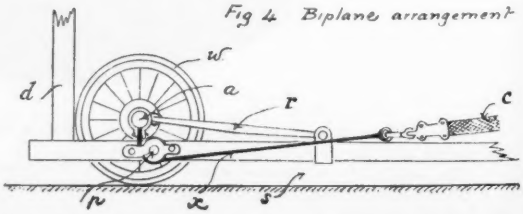


Fig 4 Biplane arrangement

NEW BOOKS AND PUBLICATIONS

*Grundlagen der Ballonführung. Dr. Robert Emden. Leipzig: B. G. Teubner. 1910. pp. 140. 2 marks 80.

*Moedebeck's Taschenbuch für Flugtechniker und Luftschiffer. Edited by Prof. Dr. R. Süring. Berlin: M. Krayn. 1911. Third Edition. pp. 920. 10 marks.

Der Maschinen und Vogelflug. Josef Popper. Berlin: M. Krayn. 1911. pp. 103. 2 marks. (This excellent work will be reviewed in the next issue.)

*The Theory and Practice of Model Aeroplaning. V. E. Johnson, M.A. London: Spon. 1910. pp. 148. 3s. 6d. n.

*The Aeroplane: An Elementary Text-book of the Principles of Dynamic Flight. T. O'B. Hubbard, J. H. Ledeboer, B.A., and C. C. Turner. London: Longmans, Green. 1911. pp. 127. 2s. 6d. n.

*Elementary Aeronautics. A. P. Thurston, B.Sc. London, Whittaker. 1911. pp. 126. 3s. 6d. n.

How to Build an Aeroplane. R. Petit. Translated by T. O'B. Hubbard and J. H. Ledeboer. London: Williams and Norgate. 1911. 2nd Edition. pp. 118. 2s. 6d. n.

The Gyroscope. V. E. Johnson, M.A. London: Spon. 1911. pp. 52. 1s. 6d. n. [A sound and welcome introduction to a most fascinating study, with good illustrations].

*Report on the Theory of a Stream Line past a Plane Barrier and of the Discontinuity arising at the Edge, with an Application of the Theory to an Aeroplane. Sir G. Greenhill. (Advisory Committee for Aeronautics: Reports and Memoranda, No 19). London: H.M. Stationery Office, 1910. pp. 86. 5s. n.

*The Principles of Aeroplane Construction. Rankin Kennedy, C.E. London: Churchill. 1911. pp. 137. 5s. n.

Aéro-Manuel, 1911. Répertoire Sportif Technique et Commercial de l'Aéronautique. Ch. Faroux et E. Bernard. Paris: Dunod & Pinat. 1911. pp. 504. 10 francs.

*Bird Flight as the Basis of Aviation. Otto Lilienthal. Translated by A. W. Isenthal. London: Longmans, Green. 1911. pp. 142. 9s. n.

*Pour Devenir Aviateur. P. Clavenad, Officier aviateur. Paris: Librarie Aéronautique [1911]. pp. 43. 1 franc.

L'Aviation. Paul Painlevé et Emile Borel. Paris: F. Aclan. 1911. 4th Edition, revised and enlarged. 3 francs 50.

Report on Balloon Experiments at Blackpool, 1910. Captain C. H. Ley. Reprinted from the Quar. Jour. R. Met. Soc. Vol. XXXVII. No. 157. Jan, 1911. pp. 33—72.

*Aeronautical Classics: No. 6.—The Flight of Birds. G. A. Borelli. London: Aëronautical Society of Great Britain. 1911. 1s. n.

The Aeronautical Classics. Edited by T. O'B. Hubbard and J. H. Ledeboer. pp. X.+ 40+ X.+ 45+ XXI.+ 40 +VI. +27+ XX.+ 39 +VIII.+ 40. London: Aëronautical Society of Great Britain. 1910—11. 7s. 6d. n. (The six classics handsomely bound in one volume with title page, list of contents, and addenda to bibliography.)

*The Aviation World, Who's Who and Industrial Directory. Second Edition. London: Aviation World Publishing Co. 1911. pp. 320. 2s. 6d. n.

*The Aeroplane: Past, Present and Future: C. Grahame-White and H. Harper: London: Werner Laurie: 1911. 15s. n.

Der Kamf gegen den Kreisel. Joseph Hofmann. Berlin: Reprinted from "Allgemeine Automobil Zeitung" Feb. 10, 1911.

*L'Aviation aux Armées et aux Colonies. General H. Frey. Paris: Berger-Levrault. 1911. pp. 165. 3 francs 50.

La Resistance de l'Air et l'Aviation. G. Eiffel. Paris: Dunod & Pinat. 1910. pp. 156 (text) Numerous plates. 20 francs. (This, perhaps the most important work in aeronautical science, published in recent years, will be fully reviewed in the next issue.)

*Reviewed in the present issue.

REVIEWS

The Aviation World. Who's Who and Industrial Directory. (London: Aviation World Publishing Co., 1911. pp. 320. 2s. 6d. net.)

It is a pleasant thing to welcome any tangible evidence of the progress of aviation as a science, as a sport and as an industry; and the book which lies before us may be greeted warmly. The contents are a directory of Societies, clubs and kindred bodies, a business directory of firms in Great Britain, France, Germany, and the United States, a list of certificated pilots of periodicals, and a mass of miscellaneous information. The book conveys the impression of having been very hastily rushed out, and we gather that this was so. The idea is excellent, and with careful extension and editing, good indexing, and vigorous insistence on the *bona fide* of advertisers, we predict a rosy future for the "Aviation World," which even now is a necessity to all interested in the most splendid game man ever put his hand to.

Report on the Theory of a Stream Line past a Plane Barrier, and of the Discontinuity arising at the Edge with an Application of the Theory to an Aeroplane. By Sir George Greenhill. Advisory Committee for Aeronautics. Report No. 19 (London, H.M. Stationery Office, 1910. pp. 96. 5s. net.)

THERE are two widely differing points of view from which this work may be approached; that of the mathematician, and that of the "practical man." The first-mentioned cannot fail to be grateful for the painstaking labours of the distinguished author in pursuit of his object, which, as stated by him, is to make a "collection for reference of the chief results in the 'Theory of Discontinuous Fluid Motion,' so far as it has been carried at present, with extensions such as those on Vortex Motion, likely to be useful in Artificial Flight."

The work consists of 96 fcp. pages of text and 13 sheets of diagrams. Roughly calculated, there are on the average, about 8 lines of the vernacular to each fcp. page, the rest being mathematical equations of varying degrees of complexity.

"The problems considered are such as that of a current impinging on a plane surface, like the wind against a wall, the sail of a ship, or a flat aeroplane; and the associated questions also of the efflux of water in a jet, discharge through a weir, or flow of a river through the piers of a bridge."

Whether the results obtained are commensurate with the large amount of work entailed is a point which can only be settled, from a mathematical point of view, by a highly trained mathematician. The treatment of the subject is of a very advanced character, and presupposes a thorough acquaintance with the mathematician's theory of fluid motion. Those mathematically inclined will find in the book a never-failing source of inspiration. The "practical man" who is beguiled by the alluring title into purchase will probably find some initial difficulty in adequately appraising the value of his acquisition. In this he will be justified, for truth to tell the book has little to interest him, and he will probably regard it as a collection of mathematical *tours de force* with small relation to practical aeronautics. When he requires, for instance, to find the dimensions of a rudder-plane to give a certain desired reaction he will go to empirical formulae founded on Dr. Stanton's curves rather than to equations founded on analytical theory. He may, in addition, point out with some reason that many of the most important points upon which he is working in the dark are precisely those upon which the mathematician, as such, is able to give but little assistance. The underlying difficulty is the lack of certain vital experimental data. These it is the task of the practical man to obtain. He does it at times by rule-of-thumb methods and in a foolhardy manner, and this is extremely regrettable.

It would doubtless be expecting too much of human nature to ask that the mathematician and the practical man should make up their minds to co-operate. Only, however, by a reasonable combination of the methods of both can the best results be obtained. If, therefore, the Advisory Committee were to lay their heads together and produce a volume giving *a quantitative comparison between solutions of problems as calculated mathematically and as obtained by actual experiment*, they would clear the ground enormously, and incidentally would do something towards fulfilling the function which the average man (doubtless from the depths of his ignorance) considers that they exist to perform. The publication of an expensive work, such as this, giving no results or deductions in English, is highly to be regretted.—B. G. C.

Pour Devenir Aviateur: Considérations sur la conduite des aéroplanes. Par P. Clavenad, Officier Aviateur (8e Chasseurs à pied). Paris: Librairie Aéronautique (1911). pp. 43. 1 franc.

This little pamphlet, though it contains less than 50 pages, demands serious consideration. In the first place, it is by a French officer, and, secondly, Lieut. Clavenad is an aviator; that is to say, the subject is approached practically, simply and directly, in the light of experience, in the interests of utility.

As a preliminary, our author discusses the qualifications of one who would fly, and proves in a conclusive manner that knowledge of motoring, contrary to accepted opinion, is not essential. The conditions, as he points out, are quite dissimilar. There are no paths to be kept, no corners to be negotiated, and very little traffic to be avoided in the air; the motor is not touched during flight except to advance, retard, or cut off the spark, and perhaps to regulate the mixture or the lubrication; and the sensation of speed, by a natural optical delusion, diminishes as the altitude increases. Little or no knowledge of the theory of flight is required, the one thing needful being an infinite capacity for making up the mind and acting promptly.

The fundamental faults in existing types of aeroplanes are stated to be two: (1) irrational controls, and (2) the sensitiveness of the machine. Lieut. Clavenad is an ardent advocate of control by natural movements, and points out that military flying schools, having no axe to grind, will assist in simplifying flight. Hitherto, in his opinion, several constructors, by rendering the control of their machines so difficult as to limit the number of their pilots, have sought by this means to reduce the number of competitors for aerial prizes.

The Lieutenant, in the absence of automatic stability, would combat the second and more important fault by developing in the would-be pilot "les centres nerveux appropriés," and to

this end he describes a mechanical tutor, designed for Antoinette pilots and in use at Mourmelon, which resembles the two halves of a walnut shell placed one on top of the other.

The bête noire of flight is the difficulty in knowing the angle of the machine, and in keeping it horizontal. Our author proposes " une espèce de grillage à barres orthogonales " placed between the pilot's line of vision and the ground, which by night could be made phosphorescent. In this way, the slightest deviation in a perpendicular direction could be detected. Finally, a scheme for training aviators starting with the mechanical tutor is mapped out in detail, for, as he truly says, the general weather conditions are so adverse to the scholar, that from the point of view of time alone the mechanical tutor is essential. The brochure concludes on a note of patriotism, visualising at the outbreak of war, a cloud of aeroplanes rising, capably handled, from all over France to instil the home-land with confidence and its enemies with consternation.

The lesson of the pamphlet—as the reviewer reads it—is the need for automatic stability and for a machine which, whether rising or descending, still preserves of itself a horizontal position. (The only machine which seems capable of both conditions is the Dunne biplane, though the last was certainly fulfilled by the Langley model.) With such a machine the altitude in flight would be controlled entirely by the motor, and the elevator would be used solely for the purpose of getting off the ground (and perhaps in emergencies for the " vol piqué "), thereafter being locked in a normal position, and only the lateral controls used.

If the aeroplane is to be of any real military or civil value, the strain on the pilot must be decreased and the efficiency of the machine increased. And this will be and is being done.

—T. O'B. H.

Aeronautical Classics: No. 6.—"The Flight of Birds." By G. A. Borelli. (London: Aëronautical Society of Great Britain, 1910. 1s. n.)

This sixth number of the Aeronautical Classics is a translation of Borelli's well known book, " De Motu Animalium," and gives the views of the author on the flight of birds.

Commencing with a brief biographical notice, the Editors have very carefully translated the twenty odd sections in which Borelli discusses the subject, and the members of the Society have now before them a clear and accurate account of the principles of bird flight, as detailed by a careful observer and distinguished scientist.

The actual text is divided into a number of short sections, explaining the construction of a bird's wing, the methods by which support and forward motion are obtained, the arrangements for rising, descending, etc., etc.

The principles laid down (with the exception of the muscular power estimates) are sound, and the whole work will be found very helpful by those who wish to study this important subject.

The Editors are to be congratulated on their translation, which, while clearly explaining Borelli's views, well preserves the original style of his work.—J. D. F.

The Theory and Practice of Model Aeroplaning. By V. E. Johnson, M.A. (London: Spon, 1910. pp. 150. 3s. 6d. n.)

This is a most useful book; in fact, it may be said to be the standard work on the art of Model Aeroplaning. The author has certainly succeeded in treating the subject from a broad and comprehensive standpoint, and although many of his own models are illustrated and described, he appears to be quite free from bias as to the merits of any particular type. The general practice and principles are dealt with in an extremely concise and interesting manner, and in the details care has been taken to go well down to the bed-rock of the science, without at the same time wasting space unnecessarily with elementary explanations. It is interesting to note that the author has now somewhat altered his former opinion as to the value of scale model experiments in relation to full-sized machines, and he now considers that these, if properly applied, should be of much assistance to the aeroplane designer.

The book opens with a short glossary of terms; in the introduction flying and scale models are discussed, and reference is made to the difficulty experienced with tailed models, like the Bleriot type, in getting the c.g. sufficiently far forward; there does not seem any way of overcoming this so long as the motive power is furnished by an elastic skein.

In Ch. I. the author lays great stress on the question of weight. " WEIGH EVERYTHING!" is his injunction, and this is one of those points which can scarcely be over emphasized, though he particularly refers not so much to the weight *per se*, as to its reaction upon, and relation to, the remaining factors in flight. The subject of resistance is fully discussed in Ch. IV.; on page 11 $f = \ldots\ldots l^{9\cdot3}v^{1\cdot85}$ should read $f = \ldots\ldots l^{\cdot93}v^{1\cdot85}$.

Section 1. of Ch. IV. deals with motive power and rubber motors, and gives a series of results obtained by varying the cross section, length, and number of strands, size of coils, etc. Mr. Johnson rather condemns the use of soap as a lubricant for rubber, and recommends pure glycerine. Ordinary soft soap, however, does not seem to have any deleterious effect on elastic.

In Section II., Ch. IV., which covers other forms of motors, the author shews conclusively that an effective small compressed air engine for models, though a simple proposition in theory, is by no means so easy to make, and use successfully in practice.

In Ch. V. on propellers, lines 5 and 6 on p. 65 read, " Suppose the diameter 14 in., and the pitch three times the diameter, *i.e.*, 52 in. . . ." This is evidently a misprint for 42 in.

Ch. VI. deals with sustentation, the centre of pressure, and camber, and all this is explained in a clear and interesting way.

The list and illustrations in Ch. VIII. of useful fittings for models might perhaps with advantage have been much increased in number.

Ch. XII. includes sheets for experimental records, and dwells on the paramount importance of directional control in model contests.

Ch. XIV. contains useful notes, tables, and formulae. There is also an appendix with descriptions of the best known types of model aeroplanes.

The book is excellently printed, well bound, and is one which no one interested in models can afford to be without.—H. F. L.

Moedebeck's Taschenbuch für Flugtechniker. Ed. by Prof. Dr. R. Süring. (Berlin: M. Krayn, 1911. 3rd edition. pp. 920. 10 marks n.)

This, the 3rd German edition of Colonel Moedebeck's famous " Pocket-book of Aeronautics," has been considerably enlarged and rearranged and may fairly be considered to be of materially enhanced importance. The lamented death of Moedebeck (there is an excellent portrait as frontispiece) in 1910, while it withdrew from the ranks of aeronautical " personalities " one of outstanding merit, has not prevented the fuller development of his encyclopædic scheme—in this new edition, the work has evolved, in the hands of Dr. Süring, into a most complete collection of essays on all matters concerning aerial navigation by men of recognised authority.

What alteration has been made is all in the direction of greater usefulness and lucidity. A considerably larger space is devoted to dynamic flight by machines heavier than air, and this now most important section is very fully and adequately treated. Chapter XII. for instance, is an exhaustive study of bird-flight. XIII. is a detailed account of the many gliding experiments suggested or executed—from Da Vinci to the Wrights—on which to-day's marvellous development of the science is mainly founded. Here, as in all other sections of this book, the excellent method is adopted of classifying the experiments—after a preliminary detailed examination of the special subject—in chronological order.

Chapter XIV., " Flight-Technics," is, perhaps, the most important. The material covered by Lanchester's " Aerodynamics " is compressed into some 100 pages by Prof. Wagener and Dr. Pröll. Though brief, it is a complete and detailed study of the vitally important theories underlying the modern flying-machine. It covers, fully, the behaviour of flat and curved planes and surfaces, and all such established facts as have grown out of the research and experiments of, say, Wenham, Lanchester and Phillips, and the practical work of Lilienthal, Pilcher, and Chanute.

Details, such as constructional points, and even covering materials, are not overlooked. The chapters on Engines (XV.) and Propellers (XVI.) are adequate and up-to-date. The last, especially, on propulsion, has been treated by Dr. Pröll most completely and exhaustively.

This edition has been brought fully to date—December, 1910—and, wherever we have been able to test it, is accurate and reliable.—A. T.

Grundlagen der Ballonführung. By Dr. R. Emden. (Leipzig: B. G. Teubner, 1910. pp. 140. 2 marks 80.)

This admirable object-lesson in Teutonic thoroughness is devoted solely to the problem of the Balloon—free or captive—and will be of very great value to those associated either with the " sport " or the more scientific use or construction of balloons. It is a very complete study of the subject, and every possible factor appears to have been considered.

The mathematics of the problem are adequately handled, and the theorist or experimenter will find the fullest information; while, for the advantage of the general reader, the important points have been resolved into concrete examples and a number of excellent tables.—A. T.

The Aeroplane: An Elementary Textbook of the Principles of Dynamic Flight. By T. O'B. Hubbard, J. H. Ledeboer, B.A., and C. C. Turner. (London: Longmans Green, 1911. pp. 127. 2s. 6d. n.)

This work goes far to meet the rapidly increasing demand for a capable elementary text-book of the principles of dynamic flight. Given judicious development in future editions, there would seem good prospect of its eventual occupation of the position in our schools and colleges for which the authors have designed it. The very fact, however, that it is designed to fill such a position makes it necessary to subject it to much more searching criticism than would otherwise be the case. If the definition be accepted that a text book should be a model of all that is exact, both in matter and form, any detail, however slight, likely to mislead the student, must be eliminated. It is undesirable to pass by the title without comment. The foreword states that the " purpose of the present work is to provide a complete text-book of the elements of dynamic

flight." There are important elements of dynamic flight not exemplified in the aeroplane. The adoption therefore of a catchy main title which stultifies the sub-title and aim of the work is an expedient which the scientific good sense of the authors will doubtless guard against in future editions. In view of the present unsettled state of the science of flight it is almost impossible to keep controversial matter out of a book such as this, and the claim in the foreword that such has been done is not only incorrect, but unnecessary. Such controversial points as arise from certain necessary assumptions in the body of the work would best be dealt with in an appendix. A brief resume of them would suffice. In addition, the bibliography which appears at the end of the book might be linked to such an appendix by indicating in the case of each work mentioned what particular controversial points, if any, were elucidated therein. (The title of a book is inadequate for such purpose.) The adoption of the above proposals would greatly facilitate the following up of points by the earnest student.

Par. 3, Chap. III., suggests that there is an essential difference between the flow of air and water which renders comparison impossible. This is precisely one of the controversial matters upon which further enlightenment should be afforded the student in the appendix above suggested. There is a marked tendency among many advanced investigators to consider both air and water as exhibiting similar fluid tendencies, differentiated mainly by their contrasted densities. In the formation of vortices, for instance, the air is by no means essentially different from water.

The explanation given in Par. 6 (Chap. III.) of the effect due to the slip of air over the side edges of a plane is likely to mislead the student. To say that the energy of the air which so escapes is wasted is to suggest that the reaction obtained by displacing the air is due to the *impact* effect on the face, rather than to the *suction* effect on the back. The side-slipping of air reduces the reaction obtained because it fills up the rarefaction on the back and renders it less intense. This point should be brought out, as the student is only too likely to accept the impact error unless emphatically warned.

The "aspiration" theory is apparently encouraged in Par. 9 (Chap. III.). This is another point suitable for the suggested appendix. It should be pointed out that the alleged experimental proofs of a curved plane having advanced "into the wind," are capable of explanation without invoking the aspiration theory.

On page 78 a misleading reference is made to dihedrally set-back screw propeller blades. This setting back is for the purpose of utilising the centrifugal flow outward from the boss. It was first patented for use in water by Lord Dundonald over 60 years ago, and is still used largely in marine work. (No reference is made to Col. Renard's ingenious setting *forward* of the blades to enable the thrust-stress on the blade to be neutralised by the centrifugal-stress.) In any event the effect said (on page 78) to follow from sloping back the blades is of too hypothetical a nature for inclusion in an elementary text-book.

Par. 37 (Chap. VI.) on helicopters is inadequate. It apparently attributes to the inclined plane some magic property by which it creates power, instead of recognising it as simply a form of gearing for altering the relation between the two factors in a foot-pound of energy.

It is somewhat inconsistent to say on page 71 that the blade of a screw propeller is simply an inclined plane and then on page 80 to imply that there is a fundamental difference between an aeroplane wing and the blade of a helicopter. The real reason for the inefficiency of the latter as compared with the former is not mentioned.

The par. on Electric Motors would best be relegated to the appendix suggested. The conception of an aeroplane of the future "propelled simply by an armature between two electro-magnets" is delightful, but seemingly too cryptic for insertion in the main body of the work.

The book is remarkably comprehensive and the treatment generally excellent. The chapter on Navigation is very good. The important points of stability and propulsion are, however, deserving of even more adequate treatment than is accorded them, and there are some statements in these chapters which it would be difficult to justify. For instance, the statement that any excess of power applied to an aeroplane after a certain speed is reached "will serve only to lift it out of its path, and will not cause it to go any faster" is mechanical nonsense. The point intended to be brought out relates no doubt to the changed "attitude" and consequent change of path which may (failing adjustment) result from driving an aeroplane beyond its designed speed. This change of attitude is due to a departure from the normal correct relations existing between the line of propeller thrust and the centres of gravity, head-resistance, and sustentation. In ordinary machines the effect (which might be downward in certain designs), would be corrected by adjustment of supplementary planes.

A certain looseness of expression is noticeable in places which is out of place in a text-book, the home of exact science. The use throughout of the French metric system can be heartily endorsed, but not so the use of the French "ornithoptère," with its pronunciation pitfall. Why not ornithopter?

When the above-mentioned points of cavil are corrected it will be possible whole-heartedly to recommend the book for the purpose for which it is produced. It is undoubtedly the best of its kind yet published in England.—B. G. C.

Interim Report of the Advisory Committee for Aeronautics; 1910–1911. (London: H.M. Stationery Office, 1910. pp. 30. 1s. 2d.)

Following hard upon the heels of the complete first Report (for 1909-1910) of the Advisory Committee, the present Interim Report contains little of interest save the tests of light motors for the Alexander Prize Competition, to which, in fact, it is chiefly devoted. Both the nature of the testing apparatus installed, for this purpose, at the laboratory, and the results of the tests are already generally known from previous publication; it may be added that the present Report contains new matter in the form of autographic records of speed and torque taken throughout the endurance tests.

Some brief notes, retailing the progress of work in other branches, since the publication of the first Report, contains information that, although very sketchy in value, possesses points of interest. It appears that the work now proceeding partakes more than hitherto of the nature of advisory help to the various Government Departments—at Farnborough and elsewhere; consequently it relates chiefly to problems connected with the dirigible. A series of balloon fabrics have been tested for strength, permeability, durability, etc. The permeability tests reveal the fact that some samples of light proofed silk have a hydrogen-containing capacity equal to that of the best and heaviest rubbered fabrics; in addition proofed silk gives a lower permeability with increased temperature, while the rubbered fabrics show a rapid increase of permeability at higher temperatures. Again, in the durability tests, proofed silk showed an decrease in permeability after an exposure in the open of fifty days, while in the case of rubbered fabrics the increase was considerable. The tests now in progress include the effect of protective colouring, absorption of moisture, the relation qualities of diagonally doubled and parallel-doubled fabric, and bursting tests. In the wind-tunnel and the water-channel tests on the resistances of variously-shaped bodies have been continued, but no results are given. Meteorological research, relating chiefly to the investigation of gustiness and possible vertical or rotary motion in the atmosphere, are being pursued at Pyrton Hill by Mr. J. S. Dines.

Some modifications have been made in the whirling-table designed to secure greater sensitiveness in the determination of the thrust and torque of propellers in motion. Arrangements have been completed for testing specimen propellers submitted by private firms and individuals. It may be useful to set out the following conditions that should be observed by applicants: diameter preferred, 2 ft., but may be up to 2 ft. 6 in. The boss should be left solid, and should have an axial length not exceeding 1½ in. Propeller speed not exceeding 4,000 r.p.m.; propeller torque not exceeding 20 inch-lbs.; speed of translation not greater than 3,000 ft. per min. Applicants should state the precise speeds of translation corresponding to the speeds of rotation at which the efficiency is to be determined; the fees will depend on the number of such observations required.

J. H. L.

L'Aviation aux armées et aux colonies. By General H. Frey (Paris: Berger-Levrault, 1911. pp. 168. 3 francs 50)

This book should attract a considerable amount of attention, written as it is by a distinguished French general, who, to a natural literary talent, has added practical experience of commanding an expeditionary force in the field, and who has served, both in peace and war, in the French colonies. There have been some friends of military aviation who, in their enthusiasm, have done the cause they have at heart some harm by putting forward arguments which ignore several powerful factors; and to them I would recommend "L'Aviation aux armées et aux colonies," because its author endeavours to give the correct value to all possible influences, and, true to the teaching of the master-mind on war, values the moral above the physical.

While reading this book it is well to bear in mind that it is written by a French officer on the effect of a new factor in war with special reference to his own country, and in consequence some of his deductions will require modification when considered with reference to an island Power. General Frey has treated his subject in separate steps—first aviation and its general effect on the land and sea forces, then as to how it will affect the various arms individually, then its effect on the colonies and colonial wars, and finally general conclusions. The book would have an increased value for the general reader if it were clearly shown what the author considers can be expected from the existing aeroplane in war, because it is on such a statement that all subsequent application of its uses must be based.

It would serve no useful purpose to give the arguments of the author in any manner less clear than his own, and it is better to content oneself with giving the effect after following the evidence placed before one. The author shows by examples taken from within the last fifty years that a new invention can seriously alter naval and military strategy and tactics, and claims that they require further and greater alteration by the introduction of the aeroplane. He further shows in detail what, in his opinion, will be the effect, and sums up by the question: "May not the command of the air be of such importance that the Power who loses it may be forced to sue for peace?"

No one can question the need for the fourth arm at the present minute, and if aviation continues to advance at its present rate a new service will be a necessity.—B.

Bird Flight as the Basis of Aviation. By Otto Lilienthal. Translated by A. W. Isenthal. (London: Longmans, Green, 1911. pp. 142. 9s. net.)

Mr. Isenthal deserves the hearty thanks of all English aeronautical workers by his exceedingly able translation of this very valuable work, the printing and general appearance of which leaves nothing to be desired.

In future editions, for which a great demand can be prophesied, the following slight alterations are suggested:—

1. On page 56, that the English symbol of "W" be used instead of the German "G" for weight, and that of "S" instead of the German "f" for surfaces would be much more generally understood.

2. On page 49, it should be explained that the results obtained are only true for the planes actually tested.

Referring to pages 65 to 68, it is a pity Lilienthal did not test the ordinary sections as now used, although it is a fault for which present-day experimenters are also open to blame, notwithstanding his results compare very well with the latest ones.

It is now twenty years since Otto Lilienthal published his systematic account of the conditions governing mechanical flight modelled upon birds.

Up to a comparatively recent date many fantastic ideas were rife as to the causes that enabled birds to fly, and to him is certainly due the merit of solving the mystery by purely mechanical and dynamic propositions, which, although incomplete in some respects, yet made it possible for subsequent workers to fill in the gaps or to rectify some of his earlier assumptions, which do not detract from his unquestionably great merits. Facilities such as wind tunnels and lofty towers were then non-existent, and he had to originate and construct all his apparatus.

He can certainly claim to be the Father of gliding experiments, and although his own country did not profit by them they bore ample fruit in others, as witness the work on the same lines done by Chanute, Pilcher, Wright Bros., Ferber, and many others; indeed, it may be said that modern aeroplanes are their lineal descendants. The wonderful economy of nature as exemplified by the flight of the larger birds was his constant ideal, and with an engineering equivalent, a partly beating wing, he hoped to solve the problem.

We have been content to perfect his gliders and to relegate the propelling function to the screw propeller, admittedly an inefficient mechanical device, rendering flight only possible when travelling at a very high speed. The few crude attempts to construct flapping wing machines were not conclusive enough to show the possibilities of a more economical form of flight by combining the lifting and propelling surfaces in one plane. From this point of view the marvellous improvements in the petrol motor has no doubt set back the development of the ideal aeroplane.

G. P. D. S.

The Principles of Aeroplane Construction. By Rankin Kennedy, C.E. (London: J. & A. Churchill, 1911. pp. 137. 5s. n.)

Is the book worth reading? That is the first question which the review of a book should answer, and when the answer is so emphatically no, one would prefer to let the matter rest there. But, unless the reviewer speaks with acknowledged authority, he must support his opinion by evidence from the book itself. In the present instance the difficulty is not so much to find passages for criticism as to select the most typical. Perhaps the commencement of Chapter II. is as typical a passage as any. The subject is "Principles of inclined planes." Having given (p. 11) a correct definition of the resultant of two forces acting on a point, the author proceeds to show how poorly he understands his own definition, thus:—

"Let **P** represent the pull, or push, moving a body F up the plane, the direction of the force **P** being parallel to the base of the triangle. The vertical arrow represents W the weight of the body. And R normal to the plane is the resultant of the two forces **P** and W."

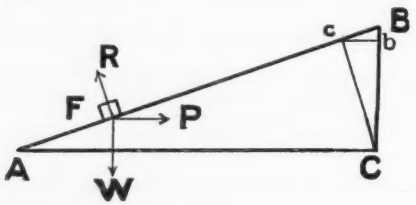
Then, after reminding the student in the words "the weight raised=W," that the body is moving up the plane, he proceeds to show that if W=6 and **P** is found to be = 1, than $\frac{BC}{AC} = \frac{1}{6}$. The enquiring student must wonder what would happen were he to exert a greater horizontal pull than one-sixth of the weight. This error is almost immediately corrected as follows:—"If there were no friction on the inclined plane when **P** is proportional to BC and W to AC, the forces **P** and W would be in equilibrium, and the body would be balanced between the two." But here, of course, we have another elementary error of a particularly flagrant kind.

And again the next paragraph is quite typical:—If W=1 lb., the work done to raise 1 lb. 10 ft. per second = 10 ft. lb. The pull P travels in the same time 60 ft., and as the ft. lb. in the pull must equal the ft. lb. in the lift, $P=\frac{10 \text{ ft. lb. per. sec.}}{60 \text{ ft. lb. per sec.}}=\frac{1}{6}$ lb.

Leaving elementary dynamics the author proceeds to unfold the "principles of the aeroplane" with equal inaccuracy.

For example we have:—"The cubic feet of air acted upon is equal to Q=cubic feet=A.V.BC."

A having been defined as an area, V in this case is a velocity (though velocities and accelerations and "the velocity of acceleration" are substituted for one another with such calm complaisance that we can never be quite sure what V does represent) and BC a length parallel to the direction of V.



Two lines lower down the inconvenient BC drops out, only to reappear a couple of lines later. A few pages later the difficulty is ingeniously evaded by taking a numerical example in which BC=1, and here incidentally we discover, what no doubt we guessed from the first, that Q represents cubic feet acted on per second.

This class of calculation constitutes the greater part of the book, but even the author's personal opinions on practical matters fail as a rule to carry conviction. For example:—"The idea of the small angle of incidence is a relict of ancient aeronautics, surviving from the times of gliders." "Many simple mechanical devices could be easily designed to give an automatic lateral balance," and "The biplane is the better machine in every way, and has been proved so in practice." The author is, of course, entitled to his own opinions, but it is indefensible, in what is presumably intended to be a text-book for students, to state as facts what are merely personal opinions on controversial questions. Thus, the "dipping front edge" is unequivocally condemned, as is the dihedral angle, the object of which the author appears to be ignorant of.

Enough has perhaps been said to indicate the nature of the book, but it seems a pity that, in these enlightened days, some sort of censorship cannot be established to prevent the publication of text books which are useless—or worse.—A. D. CARDEN.

Elementary Aeronautics. By A. P. Taurston, B.Sc. (London: Whittaker & Co., 1911. 126 pp. 3s. 6d. net.)

While there is no branch of engineering science that reposes on less complicated first principles than the science of aeronautics, neither is there a branch of science worse provided in the matter of elementary text-books. An excuse may be sought in the comparative youth of aeronautics but its underlying principles have been known, albeit not generally, for the last 40 years. The true reason probably should be sought in the lack of experimental data; theory—although, as the event has proved, mainly correct—has never been verified in practice until late years. One of the most encouraging signs of the times, therefore, is the research work now being carried out, partly by public institutions and mainly by private endeavour. The first fruits of one of these workers are embodied in the book under review, which mainly consists of lectures delivered by Mr. Thurston at the East London College. Some of these papers have already appeared in the AËRONAUTICAL JOURNAL, but, fitted into their proper sequence, they unquestionably gain in value. In collected form these papers certainly form an attractive and handy elementary treatise.

The most difficult point in writing an elementary work on so inchoate a branch of science is the process of selection. It is impossible to avoid controversial matter, and it is likewise inadvisable to qualify every statement, since qualifications pushed to an extreme—and if due regard be had to simple truth, practically every fact in aeronautical science demands qualification—inevitably lead to confusion. Mr. Thurston, therefore, has, in the reviewer's opinion, chosen a wise course in setting down his facts simply and straightforwardly.

One of the most interesting features of his work is the reproduction of many photographs illustrating the flow of air about variously-shaped bodies and propellers obtained by means of a

smoke-jet. Had the diagrams reproducing lift-and-drift and resistance curves been executed with the same care, the value of the work, and especially its appearance, would have been materially enhanced. The centre-of-pressure curve on p. 13, for instance, and the diagram on p. 19 illustrating the flow of air about an "aerocurve," are forcible instances in point. An elementary text-book, obviously, must suffer from lack of completeness; but there is at any rate one serious omission that calls for explanation: no mention is made of the method whereby the photographs were obtained. To judge of their value it is, for example, essential to know whether the smoke-jet was injected into an air-current or whether it was projected in still air, but no information is vouchsafed on the point. So, too, in the brief introductory remarks on the properties of the air, if the facts were worth setting down at all they should have been set down accurately. There is no further trouble involved in stating that air is 777 times lighter than water than in putting down the unsatisfactory statement that air is "nearly 800 times lighter than water."

A few minor criticisms: Mr. Phillips was not the discoverer, in 1884, of the advantages of the curved plane as compared to the flat plane; the discovery is at least 80 years older. Otto Lilienthal was not a Danish engineer. The first correct statement of the effect of wing-warping was made by Pénaud in 1872. On page 16, the angle β is represented by the sign B, which renders the passage incomprehensible.

Generally speaking, "Elementary Aeronautics" may be thoroughly recommended to the student and engineer in the new science whose views cannot fail to be considerably extended by its aid.— J. H. L.

The Aeroplane: Past, Present and Future. By C. Grahame-White and H. Harper. (London: T. Werner Laurie, 1911. pp. 319. 15s. n.)

It is somewhat awkward to determine from what point of view this book should be approached. Perhaps the fairest standpoint is that of considering it as an over-grown up-to-date aeronautical magazine. Its value is popular and pictorial, if somewhat ephemeral. The most useful part is probably a very complete list of 700 aviators, with brief details of each. The contents include articles by Col. Capper, M. Blériot, Mr. H. Farman, Mr. H. Wright, Mr. Holt Thomas, M. Paulhan, Mr. C. G. Grey and Mr. C. G. Grunhold.

Why Messrs. Grahame-White and H. Harper should figure as the authors it is a little difficult to see, as apparently they have done no more than to edit the book. The use, too, of a title already taken by a previous publication is somewhat unhappy.

For the splendid series of photographs and the general appearance of "The Aeroplane" we have nothing but praise, and the text itself will certainly make interesting reading for the non-scientific public.

CORRESPONDENCE

THE LAWS OF AIR-SCREWS: A CORRECTION

SIRS,—In my last article (p. 23, last paragraph) the word six lines from the bottom should be "inefficient," not "efficient," and the word "has" was omitted between "attention" and "been" (5th line from bottom). Perhaps you will kindly make this correction in the next issue?

W. R. TURNBULL.

AERONAUTICS IN AUSTRALIA

SIRS,—Some time ago you requested me to report, as a Member of the Society, on aeroplane developments in Australia. There had been, however, at that time, practically nothing whatever done in the way of real flight—merely a few attempts, skips or hops at best.

You have doubtless heard of Houdini, the conjurer, making a quite short flight or two, and he was certainly the first in Australia to achieve such a result. Subsequently we had Mr. Cugnet, who should be regarded as the first to come forward as a professional aviator, but though he had a Bleriot II. machine, he disappointed the public repeatedly. His last appearance in Melbourne signalized his first public rise from the ground, but he only rose sufficiently to clear the Cricket Ground from which he started, catching the back wheels of his aeroplane in the spikes of the iron fence round the ground, causing the machine to fall into a tennis court and completely smash itself. Had he gone beyond the court, there were various obstructions and dangers, such as telegraph wires and railway lines, not to be lightly esteemed by a beginner. He may still do a flight, however, as the machine has been repaired.

Mr. Pither, who achieved some small success in New Zealand with a machine he built himself, including the (40 HP) engine, recently came to Melbourne, but has done nothing publicly. I have been consulted by him as to his prospects, but told him that the various disappointments the public had received would render it necessary for some genuine flying to be done privately before the public would have faith in any more aviators here. However, he is thoroughly genuine, has been a champion cyclist, and is an engineer by trade.

The most recent development is the first work that is worthy of the serious attention of the Society so far, as indicating flying worth the name in Australia. The aviator is Mr. J. J. Hammond, who has been flying for the British and Colonial Aeroplane Company on a "Bristol" biplane. With regard to the distances travelled, Mr. Hammond travelled some 22 miles in 31 minutes at his first successful flight, starting from Altona Bay and coming back to the starting point. His next trip was much longer and straighter, following a railway line largely, and extending from about 40 miles, taking about an hour, and not returning. Then the next day he rose from his landing point and retraced the 40 miles. It is evident that he has a good command over his machine, and has shown the people of Australia for the first time, how readily a flying machine can be operated without any excuses or pretences as reasons for not getting into the air. The engine used was a "Gnome," and several have been imported.

From this date real flying in Australia may be said to be sure to move ahead. No country surpasses us in athletics, and our men possess in the highest degree nerve and coolness, the powers of calculation, the faculty of avoiding foolhardy risks, and the absence of that persistency in starting with imperfect apparatus which has led to various accidents elsewhere. There is not any local factory so far for the manufacture and supply of flying machines, but there is no reason to fear that such a factory will not be established after a while when the demand for machines has grown stronger.

G. G. Turri.

23rd February, 1911.

THE FIRST FLIGHT IN AUSTRALIA

Sirs,—In a recent table you published the first flight in Australia as being accomplished by Mr. Defries. That is incorrect, as Mr. Defries did *not* fly in Australia, as I and other League officials were present at all his attempts.

The first Australian flight was accomplished by Mr. H. Houdini on a Voisin machine, and to whom the League's trophy was presented for that achievement.

George A. Taylor, Hon. Sec.,
Aerial League of Australia.

[We may add to this a recent first flight in New Zealand by Mr. V. Walsh at Papakura, near Auckland, on February 9, on a Howard Wright biplane.—Eds.]

ANALYSIS OF FOREIGN PUBLICATIONS

ABBREVIATIONS.

Aer., L'Aéronaute (Paris).
Aero, Aero (St. Louis).
Aeron., Aeronautics (New York),
D.Z.L., Deutsche Zeitschrift für Luftschiffahrt. (Berlin)
Rev. Aer., Revue Aérienne (Paris).
Rev. de l'Av., Revue de l'Aviation (Paris).
Tech. Aer., Technique Aéronatique (Paris)
Aerop., L'Aérophile (Paris).

AERODYNAMICS

Résistance de pénétration des véhicules dans les fluides. (Constantin). *Tech. Aér.* January 1.
A propos d'une étude de M. Riabouchinsky. (Eiffel). *Tech. Aér.* January 15.
Photographie du vent. (Lafay). *Tech. Aér.* March 15.
Nouvelles expériences du Laboratoire Eiffel en 1910. (Espitallier). *Tech. Aér.* March 15.
Recherches sur les mouvements pendulaires de plaques symétriques dans un courant aérien. (Riabouchinsky). *Aérop.* January 1.
Résistance des plans rectangulaires. (Eiffel). *Aérop.* February 1.
Déplacements du centre de pression. (Hubert.) *Aérop.* April 1.
Résistance de l'air. (Chovet.) *Rev. de l'Av.* April 1.

AEROPLANES

"Fahlbusch" monoplane. *D.Z.L.* January 11.
"Hanuschke" monoplane. *D.Z.L.* January 25.
"Grohmann" monoplane. *D.Z.L.* February 8.
"Hanriot" monoplane. *D.Z.L.* February 22.
"Bayard-Clément" biplane. *D.Z.L.* March 7.
"Heitmann" monoplane. *D.Z.L.* April 5.
"Dorner" monoplane. *D.Z.L.* April 5.
"Schulze-Herfort" monoplane. *D.Z.L.* April 5.
"Reichelt" biplane. *D.Z.L.* April 5.
"Cayre" monoplane. *Tech. Aér.* March 15.
"Moreau" monoplane. *Rev. Aér.* January 25.
"Zodiac" biplane. *Aérop.* February 1.
"Voisin" biplane. *Aérop.* March 1.
"Lasternas-Lepers" biplane. *Rev. de l'Av.* February 1.
"Coanda" biplane. *Aér.* January 21.
"Hubbard" monoplane. *Aeron.* April.
"Curtiss" hydro-aeroplane. *Aéro.* March 25.
"Etrich-Rumpler" monoplane. *D.Z.L.* April 5.
"Pischoff" monoplane. *D.Z.L.* April 5.

BALLOONS

Vertical velocity of balloons. (Leick.) *D.Z.L.* January 1.

BIOGRAPHY

Chas. Germe. *Rev. Aér.* February 25.
Alex. Anzani. *Aérop.* January 1.
G. Legagneux. *Aérop.* January 15.
J. Dubois. *Aérop.* February 1.
M. Colliex. *Aérop.* March 1.

BIRD-FLIGHT

Anatomie et physiologie du vol. (Cousin.) *Rev. Aér.* February 25.
Sur le vol ramé. (Thouveny.) *Aérop.* March 1.
Travail et puissance motrice de l'oiseau. (Thouveny.) *Aérop.* April 1.
Resistance aérienne sur des zooptères. (Amans.) *Aér.* January 14.

COMPASS

L'usage du compas dans les navigations aériennes. (Byasson.) *Aérop.* February 15.

CONSTRUCTION

How to build a Curtiss-type biplane. (Godley.) *Aeron.* February.

DIRIGIBLES

Les dirigeables Astra. *Aérop.* February 1.
"Suchard" dirigible. *D.Z.L.* February 22.

GLIDING FLIGHT.

Le vol plané. *Rev. de l'Av.* January 1.

HISTORY

Essais de l'appareil Ader. *Tech. Aér.* January 15.

HYDROGEN

Appareil Schilling, modifié par Josse, pour la détermination du poids spécifique de l'hydrogène. (Bethuys) *Tech. Aér.* March 15.

LABORATORY

L'Institut Aéro-technique H. Deutsch de la Meurthe. (Simon.) *Aérop.* March 15.

LAW

Jurisprudence de l'aéronautique. (Imbrecq.) *Aérop.* January 1.

MAPS

Projet de carte aéronautique avec repères. *Aérop.* January 15.
Une carte pour l'aviation. (Talon.) *Rev. de l'Av.* February 1.

MEASUREMENT: DISTANCE

Calcul de la distance parcourue dans les épreuves de l'aéronautique. (Vallot.) *Aérop.* February 1.
Measuring height attained by aeroplanes. *D.Z.L.* March 22.
Calculation of distance covered in balloon ascents. *D.Z.L.* January 25.

METEOROLOGY

Meteorology and aerial navigation. (Polis). *D.Z.L.* January 25.

MOTORS

Moteurs d'aviation. (Letombe.) *Tech. Aér.* January 1.
"Berthaud" Motor. *Rev. Aér.* February 10.
"Macomber" rotary engine. *Aéro.* March 11.
Aerial Motors (with table). *D.Z.L.* February 8.
"Mercedes" motors. *D.Z.L.* February 8.
"Daimler" motors. *D.Z.L.* February 8.
"Körting" motors. *D.Z.L.* February 8.
"Rumpler" motors. *D.Z.L.* February 8.

NAVIGATION

La direction en aéroplane. (Bellenger.) *Aérop.* February 15.
Les routes aériennes. (Hemmet.) *Rev. de l'Av.* January 1.
Use of the watch to localise position. *D.Z.L.* February 22.
Astronomical navigation with the Voigt instrument. *D.Z.L.* March 7.

NAVAL

Les aéroplanes dans la guerre navale. (Piumatti.) *Tech. Aér.* January 1.

PHOTOGRAPHY

Camera for photographing the car of a balloon during the ascent. *D.Z.L.* March 7.

PILOTS

Listé alphabétique des pilotes-aviateurs. *Aérop.* January 15.

PROPELLERS

Relation entre la poussée d'une hélice propulsive en marche et au point fixe. (Ziembinski.) *Tech. Aér.* April 1.
Notes on the Aeroplane Propeller. (Sellers.) *Aeron.* January.
Fallacy of the Screw Propeller. (Howell.) *Aeron.* January.

SOARING FLIGHT

Vérification par le calcul de la possibilité du vol à voile. (Sée.) *Aérop.* February 1.

STABILITY

Sur un mode d'installation du gyroscope stabilisateur. (Thouveny.) *Rev. Aér.* March 25.
Sécurité par la vitesse. (Lorin.) *Aérop.* January 1.
Stabilisation des aéroplanes au moyen de gyroscopes. (Girardville.) *Aérop.* February 15.
Stabilisation automatique. (Guérin.) *Aérop.* February 15.
Equilibre des aéroplanes. (Naret-Lefébvre.) *Rev. de l'Av.* February 1.
Stabilité des aéroplanes. (Brunet.) *Aér.* January 21.

TERMINOLOGY

Aeronautical terminology. (Dr. Poeschel.) *D.Z.L.* February 22. [With special reference to the report of the Terms Committee of the Aëronautical Society.]
Aeronautical terminology in history (Christmann.) *D.Z.L.* March 22 and April 5.

TRAFFIC

L'utilisation des aéroplanes en Indochine. *Rev. Aér.* March 10.
L'Aviation coloniale. (Cortier.) *Rev. Aér.* March 10.
A Trans-continental Aero Way. (Ehrlich.) *Aeron.* April.